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SCIENCE ABSTRACTS

SECTION A.—PHYSICS.

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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

AUGUST 1916.

GENERAL PHYSICS.

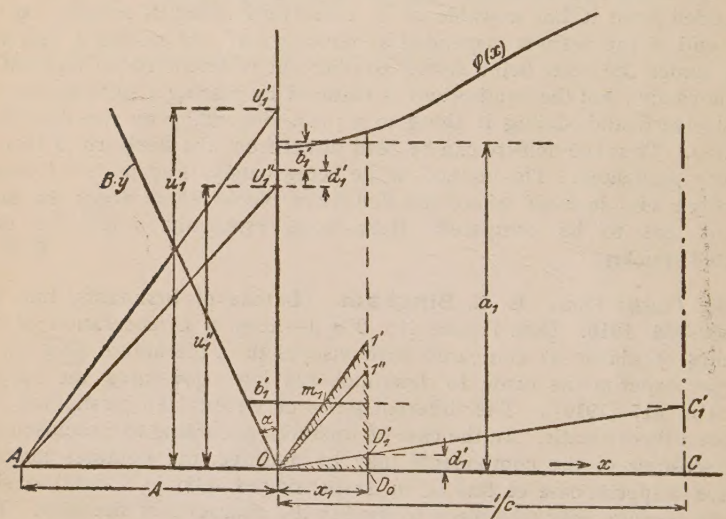
849. *The Densitameter.* **G. A. Shakespear.** (Engineering, 101. p. 587, June 16, 1916.)—A balance beam has a body whose density is required suspended from it, but movable, as in a steelyard, along its length. At the other end of the beam is suspended a counterpoise. On raising a vessel of water under the body being tested, equilibrium is destroyed on account of the buoyancy ; but the equilibrium is restored by placing a suitable load on the steelyard and sliding it along to a place depending on the density in question. Thus the density can be read direct from the steelyard, if this be properly graduated. The method, while being handy, is accurate. It seems specially useful in cases where the density of blocks, all of about the same amount, has to be compared. Blow-holes, especially, would be then detected quickly. P. E. S.

850. *Plastic Flow.* **E. C. Bingham.** (Bureau of Standards, Bull. 13. pp. 309–353, 1916. [Sci. Papers No. 278].)—After a consideration of the meaning of plastic as compared with viscous flow, the author goes on to describe experiments made to determine the laws governing the former [see Abs. 517 (1916)]. The different types of viscous and plastic flow are discussed theoretically. In the case of mixtures, according to circumstances the viscosities of the components may be additive, the fluidities may be additive (a special case of this is the suspension of solid in a fluid), or slipping or seepage may take place to modify the character of the flow. The possible separation of the components of a mixture by means of flow is also considered. It is shown that in a suspension of solid particles in a liquid there must be a dissipation of energy when the solid particles collide, as they must collide if the layers of the suspension move over each other. This dissipation of energy follows the laws of ordinary friction and not the laws of viscosity.

The results obtained in the experiments show that plastic flow can be sharply differentiated from viscous flow by the "friction" necessary to start plastic flow. As already announced [*loc. cit.*] for medium pressures the rate of flow is given by the formula $v = K(P - f)$, where P is the pressure, f is the

"friction," and K is an arbitrary constant. The experiments indicate that at low pressures seepage takes place causing a perceptible change in the concentration, and that at high pressures there is slipping which in certain circumstances may cause a sudden increase in the rate of flow. The fluidity becomes zero at the concentration where the plastic flow begins, that is, where the friction begins to have a positive value. This concentration where the particles are able to form a bridge across the capillary space, is reached long before the concentration corresponds to close packing of the solid particles. For very fine-grained materials the range between the concentration giving zero fluidity, and the concentration corresponding to close packing will be much greater than in coarse-grained material. The meaning of the term "mobility" in the case of suspensions is discussed, and formulæ are developed for its determination. The mobility decreases very rapidly from its max. value in the concentration which has zero fluidity to a value not far from zero in the mixture which corresponds to close packing of the solid particles. The mobility increases with the fluidity of the medium, but it is also greatly affected by the presence of alkalies or acids. J. W. T. W.

851. *Graphical Integration of Differential Equations of Higher Orders.* **A. Schwaiger.** (Archiv f. Elektrot. 4. pp. 269–278, 1916.)—The method given is illustrated by means of equations of the second order. The equation $A \cdot d^2y/dx^2 + B \cdot dy/dx + C \cdot y = \phi'(x)$ is put into the form $dy/dx = u/A$, where $u = \phi(x) - B \cdot y - C \cdot \int y \cdot dx$. The process of integration



is shown in the Fig. herewith ; the function $\phi(x)$ is given as a curve, and it is assumed that $y = 0$ when $x = 0$. Lengths A and 1/C are marked off on the axis of abscissæ as shown and the line $B \cdot y$ is drawn. A trial value of u is taken, say u_1', and laid off on the y-axis as OU_1' ; A is joined to U_1'. Then the slope of AU_1' equals u_1'/A and gives the slope of the integrated curve in the first interval O1'. To check the value assumed for u_1' the middle point m_1 of this part of the curve is taken and the value of $B \cdot y$ corresponding to its ordinate is found, viz. b_1' (see Fig.). The value of $C\int_{x=0}^{x=x_1'} y\,dx$ is C times

the area of the triangle shown with a shaded contour, it is equal to $C \times y'_{m_1} \times x_1'$, where y'_{m_1} represents the ordinate of the point m_1'. If CC_1' be made equal to y'_{m_1} then $d_1' : y'_{m_1} = x_1' : 1/C$, and $d_1' = C \cdot y'_{m_1} x_1' = C \int_0^{x_1'} y dx$. The value of $\phi(x)$ at the middle of this interval is a, and we should have $a_1 - b_1' - d_1' = u_1'$; if this is not so a nearer trial value can be chosen and the process repeated until a good agreement is reached. The process can be repeated for successive intervals until sufficient of the curve has been delineated. In an example the method is applied to determine the current curve in a circuit to which a sine-shaped e.m.f. is applied, the self-induction of the circuit is assumed to vary with the current according to a law expressed as a graph. The process is specially suited for application to such cases as this, for which exact mathematical solutions are not obtainable. The time taken is not very great, and an error not exceeding 5 % should be obtained when the work is done with care. F. T. C.

852. *Steel under Biaxial Loading.* **A. J. Becker.** (Univ. of Illinois, Bull. No. 85. [65 pp.], April 10, 1916.)—Describes an investigation to determine the laws governing the strength and stiffness of mild steel when subjected to the combined stress produced by two tensions at right angles to each other, or a compression combined with a tension. Throughout the investigation the ratio between the two stresses was kept constant for each specimen, and Johnson's tangent method (described in the paper) for determining the yield-point was selected. The specimens were drawn steel tubes of uniform size and thickness. These were subjected to an axial load and also to internal hydraulic pressure. By means of a portable Berry strain-gauge readings were obtained giving the distribution of stress on each of several cross-sections, the use of a portable gauge rendering it possible to take measurements on a large number of gauge-lines for each increment of load, thus obviating to a large extent the effect of local variations. In an early section of the paper the six theories hitherto advanced to cover the problems of the strength of materials under combined stresses are described. From the first (St. Venant's, or maximum strain) theory, it results that a material subjected to two tensions or two compressions at right angles is increased in strength, while a tension combined with a compression lowers the strength. According to the maximum shear theory (Guest's law), however, all failures are failures by yielding due to shear when the shearing unit stress reaches the shearing yield-point stress.

The results obtained in the experiments show that with increasing values of the ratio of the biaxial stresses the yield-point strength follows the max. strain theory until the value of the shearing stress reaches the shearing yield-point, then the shearing stress controls according to a max. shear theory. There are thus two independent laws governing the strength of ductile materials under biaxial loading, and hence a knowledge of the ratio, for simple stresses, of the shearing yield-point stress to the tensile yield-point stress is important. The experiments show, further, that the stiffness also follows the requirements of the mathematical theory of elasticity for all stress ratios, but the values of Poisson's ratio and the modulus of elasticity may be different in the two directions, with and across the rolling and drawing of the steel. The paper is followed by a bibliography and a mathematical appendix giving a brief outline of the theory of elasticity. J. W. T. W.

853. *The Basis of the General Theory of Relativity.* **A. Einstein.** (Ann. d. Physik, 49. 7. pp. 769–822, May 11, 1916.)—This paper contains a most comprehensive account of the general theory of relativity as distinct from the special theory. In the introduction, reference is made to the form given to the special theory by Minkowski, whereby the later generalisation was facilitated. The provision of the necessary mathematics was due to the labours of Gauss, Riemann, Christoffel, v. Ricci and Levi-Civita, and the present author has collected in Section B of the paper all that is requisite for the proper understanding of the various propositions described.

The subject-matter is dealt with in four main divisions. Section A, subdivided into four parts, considers the principal reasons for the postulation of relativity, and commences with a description of the special theory of relativity. Following this comes an investigation of the effect entailed by an extension of the postulates of relativity. The space-time coordinates are next treated, together with the necessity for the general covariance of the equations expressing universal natural laws. In the fourth sub-section the relationship of the four coordinates expressing space and time measurements is dealt with, and an analytical expression given for the gravitation field. Section B contains a *résumé* of the mathematics essential for the statement of the general covariant equations. The root idea of this general covariant theory is as follows: Certain quantities called tensors are defined with respect to any system of coordinates by a number of space functions which are termed the components of the tensor. Certain rules then exist whereby these components can be calculated for a new system of coordinates when the necessary transformations linking the two systems are known. Tensors are further qualified by the fact that the transformation equations for their components are linear and homogeneous. Accordingly components which disappear in one system, do so in a new system. When a natural law is formulated by making zero all the components of a tensor, then it is universally covariant. An investigation into the principles regulating the formation of tensors, therefore, will provide the means for the establishment of general covariant laws. These vectors and tensors receive full and detailed treatment in this particular section ; following which comes the equation of the geodetic line. The formation of tensors by differentiation is shown, and a special sub-section is devoted to the Riemann-Christoffel tensor. Section C deals with the theory of the gravitation field. Firstly, the equation of motion of a material point is established, and an expression obtained for the field components of gravitation. Secondly, the field equations are derived when the matter is assumed absent, the latter term including not only matter in the usual sense but everything other than the gravitation field, such as the electromagnetic field. Thirdly, the Hamiltonian function for the gravitation field is dealt with, and an impulse-energy proposition obtained. Fourthly, a general mode for expressing the gravitational field equations is considered. Fifthly, the impulse-energy proposition for matter is shown to be a consequence of the field equations. Section D considers material processes such as are dealt with in hydrodynamics, Maxwell's electrodynamics, etc. Here it is shown that these processes fit into the general theory of relativity, which latter then gives the exact influence of the gravitation-field upon them. The first sub-section deals with Euler"s equations for frictionless and adiabatic liquids, then follows Maxwell's electromagnetic field equations for a vacuum, and finally the author considers the behaviour of scales and clocks in the statical gravitation, together with the refraction of light rays and the motion of planetary orbits. On the physical nature of matter in the narrower sense, definite

assumptions must not necessarily be introduced, and the question remains open as to whether the theory of the electromagnetic field together with that of gravitation furnishes a sufficient basis for the theory of matter or not. While the theory of relativity has nothing in itself to teach on these points, yet its development may show whether the combination of the above two theories can give an explanation to the problems which the electromagnetic theory has failed to do. H. H. Ho.

854. *The Kinematical Basis for Physical Waves of Simple Vibration Type.* **I. K. Uller.** (Phys. Zeits. 17. pp. 168–172, May 1, 1916.)—The author here undertakes a mathematical investigation into the kinematics of simple waves. Section 1 of the paper deals with the state of vibration in the field and more particularly with the case of spiral rotation. Section 2 treats of the state of vibration in the wave itself. Section 3 discusses the case where the wave-equation fails. In Section 4 some special examples are considered, viz. elastic waves in an isotropic solid, and electromagnetic waves in an isotropic body. It was found that in the case of the electrical vibrations possible at the surface of an axially symmetrical body, those waves proceeding from the conductor are by no means reversible and are compound in character. H. H. Ho.

855. *Wave-patterns due to a Travelling Disturbance.* **H. Lamb.** (Phil. Mag. 31. pp. 539–548, June, 1916.)—In the present paper the same procedure as in a former communication [see Abs. 513 (1916)] is adapted to the case of propagation in two dimensions, as when a pressure-point advances over the surface of water. The method itself depends ultimately on integrals of the type $\int F(z)e^{izx}/f(z)dz$ taken round suitable contours, where the functions $F(z)$, $f(z)$ are usually algebraic, and $f(z)$ has one or more simple roots of the form $K + i\mu$, where K is positive and μ_1, which depends on an assumed frictional coefficient, is in the end taken to be infinitesimal. It is assumed for simplicity of statement that, generally, there is only one root of $f(z)$ of the above type. Various cases are considered, and although nothing very novel is claimed for the results, yet the author hopes that the generalised treatment given in the paper of a somewhat intricate problem may be acceptable. H. H. Ho.

856. *Bohr's Atom Model.* **M. Wolfke.** (Phys. Zeits. 17. pp. 198–200, May 15, 1916.)—The author has previously shown that the application of Bohr's radiation theory to the Debye hydrogen molecule leads to the Balmer series [see Abs. 561 (1916)]. The expression for the Balmer constant is $2\pi^2e^4m/h^3$, when derived from Bohr's atom model [see Abs. 15 (1914)], but under the above assumption becomes $2\cdot 2\pi^2e^4m/h^3$, where e is the charge and m the mass of the electron, while h is the Planck energy-quantum. It is of great importance to find which of these two expressions best represents the latest experimental data, and in the present paper the author endeavours to find a solution. Since Bohr's radiation hypothesis is derived from the quanta theory, the relationship between the energy quantum and the electrical element must not be disregarded, that is, h and e must be considered as inter-dependent. From this standpoint, together with the experimental data available, the author concludes that the Bohr expression for the Balmer constant is correct. The author explains his previous contrary result as a consequence of not taking into account the connection between h and e. H. H. Ho.

857. *On the Brownian Movement in Gases.* **[Miss] A. Snethlage.** (K. Akad. Amsterdam, Proc. 18. pp. 1480–1484, 1916.)—Among the different

derivations of the deviation which a particle suspended in a gas or liquid obtains in a time t, there is one of v. Smoluchowski [see Abs. 1818 (1906)], in which only kinetic considerations are made use of. According to v. Smoluchowski this derivation will only hold for gases, and that only when the dimensions of the particle are small with respect to the mean free path of the surrounding molecules. There is still something wanting in the accuracy of this calculation, for among other things equal velocities are assigned to all the molecules. The present author, using a somewhat different course, derives an expression for the mean deviation which only differs from the above-mentioned one in numerical coefficient, but in which Maxwell's distribution of velocity is taken into account. Another calculation not made on purely kinetic considerations led to the same expression. H. H. Ho.

858. *Speed of Circular and Helical Vortices.* **A. Lauth.** (Ann. d. Physik, 49. 6. pp. 671–682, May 5, 1916.)—Following the work of Kelvin and the recent (1914) more elementary method of A. Gray (without elliptic integrals) the author here derives in an elementary way the speed of circular and helical vortices. E. H. B.

859. *Growth of Crystals under External Pressure.* **S. Taber.** (Am. J. Sci. 41. pp. 532–556, June, 1916.)—Many experiments on the growth of crystals under different conditions have been carried out, some of the principal results and the conclusions derived from them being as follows :— When two crystals, similarly placed in a saturated solution, are subjected to unequal pressures, the system is in unstable equilibrium. Thus, a solution may become supersaturated with respect to a crystal placed under a relatively low pressure, while at the same time it tends to dissolve a crystal under a greater pressure; this probably explains why Bruhns and Mecklenburg (1913) failed to get the results obtained by Becker and Day (1905). These results are confirmed by the author, who finds that under certain conditions the growth of crystals may be accompanied by the development of a linear force. Whenever a measurable lifting of a weight took place, it was found at the close of the experiment that the crystal had a terraced cavity or hollow on its under side, even when the initial faces of the crystal were plane. Moreover, measurements show that the distances through which weights are lifted by growing crystals are always the same as the amounts by which their hollows are deepened.

Experiments with weighted and unweighted crystals prove : (1) that a growing crystal resting on a smooth surface can raise itself, and even a considerable additional load, by building downwards the advancing outward edge of the crystal ; (2) that no material is deposited on the under side of the crystal except along the advancing outer edge ; and (3) that the cavities are not formed by solution, but are due to the downward growth of the outer edge, while at the same time no material is being deposited on the under surface within its outer edge. All the results obtained support the theory that a crystal grows only through the addition of layers of material from without ; when crystals grow in contact with glass surfaces, a thin layer or film of solution always exists between the crystal and the glass, the presence of this film being due to capillary attraction and adsorption. The area of contact between a crystal and the supporting surface is under greater pressure than the rest of the crystal, and since the solubility of most substances in aqueous solutions increases with the pressure, the supporting surface has a greater solubility than the other parts of the crystal. The

degree of concentration necessary for growth is, therefore, greater at the base than elsewhere, and increases with any increase in the weight supported per unit area of the supporting surface. Adsorption may help in some slight degree to increase the concentration of the layer of solution in contact with the bottom of the dish, but it cannot be the direct cause of the upward pressure developed by crystals, since otherwise the presence of unweighted crystals in the same dish with weighted crystals would not prevent the upward growth of the latter ; this conclusion is supported by the absence of appreciable hollows on the upper surface of crystals grown under heavy weights or even under glass plates weighing only 0·17 gm.

The application of these results to geological phenomena is discussed.

T. H. P.

860. *Newtonian Constant of Gravitation as affected by Temperature.* **P. E. Shaw.** (Roy. Soc., Phil. Trans. 216. pp. 349–392, May 27, 1916.)—This paper deals with the possible existence of a temperature coefficient in the law of gravitation and gives an account of experiments made to discover this coefficient. The apparatus used is of the Cavendish torsion-balance type, and the range of temperatures was from 15° to 250° C. The investigation has extended over a number of years and was carried out in a vault of the physics department of University College, Nottingham. It yields evidence for a positive temperature effect of gravitation and measures its value.

The accumulation of negative results in the experimental study of gravitation is remarkable. In consequence of the indifference of the gravitative force to changes of conditions (other than those given by the simple law $f = GMm\,(d^2)$, none of the many theories of gravitation so far propounded has received general acceptance for lack of data wherewith to test them. Some recent theories which consider the possibility of temperature effect are the following: N. Morazov (1908) advanced a wave theory in which the attraction of masses would vary with temperature. G. Mie (1913) gave a theory of matter which includes among its corollaries a temperature coefficient of 10^{-13} per 1 deg. C. to the so-called Newtonian constant. N. Bohr (1913), in a paper on the constitution of the atom, assumed that gravitation like radio-activity is unaffected by all physical and chemical agencies.

Previous determinations of the Newtonian constant have been made at ordinary temperatures only, special care being taken to maintain uniformity in temperature throughout the apparatus used ; otherwise convection in the air or strains in the movable system might produce grave errors. This is shown repeatedly in the well-known researches by C. V. Boys and by J. H. Poynting. The necessity of providing a steady temperature about the delicate parts of the apparatus has previously been considered an insuperable bar to any direct experiment to discover a temperature effect for G. Yet indirect investigations have been made. Poynting and Phillips (1905) counterpoised a mass of 208 gm. on a balance and varied its temperature between 100° and −186° C. They came to the conclusion that the resulting change in weight, if any, was less than 10^{-9} per 1 deg. C. for the range 100° C. to 0° C., and 10^{-10} per 1 deg. C. for the range 0° to −186° C.

Another balance experiment on change in weight with temperature by Southerns (1906) led to a somewhat similar result.

In looking for a method to continue and extend these researches it is observed that a weight of, say, 1 gm. can be determined on a balance to 10^{-8} under favourable conditions, whereas in a gravitation apparatus, like that of C. V. Boys, the attraction of one mass on another cannot be found with

greater accuracy than 10^{-5} at the utmost. Thus, apart from other reasons, it would be futile on the latter type of apparatus to look for a temperature effect, between 100° C. and — 186° C., on the small mass, *m*, since the above negative results have established the case with the greatest possible accuracy. But, in these balance experiments of Poynting and Phillips, the large mass M (in their case the earth) was unchanged in temperature. Now M is incomparably larger than *m* and might have a preponderating influence, whereby change of *its temperature alone* would affect the mutual attraction. In the work referred to, Poynting and Phillips suggested (though without any *a priori* grounds) the feasibility of some such expression as the following :—

$$f = G\left[1 + K\frac{Mt + mt'}{M + m}\right]\frac{Mm}{d^2}, \quad \ldots\ldots\ldots (1)$$

where K is a temperature coefficient and *t*, *t'* are increments in temperatures of M and *m*. When M/*m* is very great, this reduces to $f = G(1 + Kt)(Mm/d^2)$...(2), so that, on the above supposition, the mutual attraction would be influenced by change in temperature of the large mass only.

Admitting the possibility involved in (2), weight experiments must be abandoned in the endeavour to detect a temperature effect in gravitation and an apparatus adopted, having both masses (M and *m*) under control as regards temperature.

It is supposed by some that Kepler's third law establishes the constancy of G. But the present author has tried to show [Abs. 1628 (1915)] that this is false, and that the common practice of obtaining the masses and densities of heavenly bodies (sun, earth, planets, etc.) by assuming the invariability of G is at fault. It was there held that in such a view Kepler's laws are strained beyond their legitimate use.

A survey of previous researches on gravitation is then given and affords some slight information as to temperature effect : five cases are noticed.

In this connection it may be noticed that there are three classes of work, the results from which should be distinguished. (1) Change in temperature of both M and *m* (*indirectly* by Boys, Baily, v. Sterneck) ; (2) Change in temperature of M only (*indirectly* by Mendenhall, *directly* in the present research) ; (3) Change in temperature of *m* only (*directly* by Poynting and Phillips).

In the present research a number of early experiments were made in a variety of ways. Finally, a form was adopted closely resembling the Cavendish experiment of Boys. That is to say, the small masses, *m*, *m*, were hung at different heights inside an exhausted chamber and were attracted by the large masses M, M, hung at corresponding heights, but outside the chamber. The small masses were of silver, the large ones of lead. The latter were electrically heated, their temperatures being read by mercury thermometers. The zero positions of the small suspended system were deduced by noting the turning points as read by a distant telescope and scale. Thus, the relative gravitative effects with the large masses cold and hot are found by observing the shift in each case on rotating the large masses from the one attracting position to the other.

Elaborate precautions were taken to avoid various disturbances or spurious effects. Those dealt with are electrostatic, magnetic convection, radiometer pressure, occluded gases, damping, radiation pressure, conduction of heat and displacements of apparatus. Taking all circumstances into consideration, a pressure of 14 mm. was held to be most satisfactory and was adopted in many

of the later experiments. The results of the experiments with the final form of apparatus are summarised in the table. From this it is deduced, for the given temperature range of the larger masses (of about 47 kg. each) if a linear relation be assumed, that $f = G(1 + a\theta)\,Mm/d^2$, where a is a temperature coefficient of value $(+1{\cdot}20 \pm 0{\cdot}05) \times 10^{-5}$ per 1 deg. C.

TABLE SUMMARISING CHIEF RESULTS.

Shift at 15° C.	Greatest Rise of Temperature.	Shift at Highest Temperature.	(Effect for 1 deg. C.) × 10⁵.	Comments.
57·60	150° C.	57·70	+ 1·1	Small chains and cylinders Pressure 0·001 mm.
201·9	185	202·5	+ 1·6	Silver Balls Pressure 2 mm.
209·2	200	209·6	+ 0·9	
200·8	135	201·5	+ 0·9	
200·8	180	201·35	+ 1·4	
200·8	150	201·35	+ 1·8	Silver Balls Pressure 4 mm.
200·85	160	201·25	+ 1·2 ←	Silver Balls and Pressure 14 mm. for this and all the rest
200·8	160	201·2	+ 1·3	
196·3	140	196·5	+ 0·8	
193·45	180	193·95	+ 1·3	
193·25	180	193·9	+ 1·6	
175·45	190	175·75	+ 0·9	
175·45	210	173·75	+ 0·9	
175·55	220	176·15	+ 1·5	←Demagnetise Silver Balls
175·5	200	175·95	+ 1·3	
199·5	200	199·7	+ 0·5	
201·25	210	201·65	+ 1·0	
190·75	230	191·2	+ 1·1	
185·7	150	186·2	+ 1·7	←Rotate M, M by 180°

E. H. B.

861. *Gravitation and Temperature.* **J. L[armor].** (Nature, 97. p. 321, June 15, 1916.)—As the outcome of a very delicate systematic series of experiments, it is announced by P. E. Shaw [see preceding Abs.] that when one large mass attracts a small one the gravitative force between them increases by about 1/500 as temperature of the large mass rises from, say, 15° C. to 215° C.; that is, it increases by about $1{\cdot}2 \times 10^{-5}$ of itself per 1 deg. Centigrade. This seems to be a very startling result, at any rate if temperature is merely the expression of internal molecular motions, as, indeed, the experimenter seemed to admit.

By Newton's principle gravitation between masses must act reciprocally: the result, therefore, means that the astronomical mass of a body must increase with temperature by $1{\cdot}2 \times 10^{-5}$ of itself per 1 deg. Centigrade.

The pendulum experiments of Bessel and recent determinations by Eötvös seem to establish proportionality between gravitational mass and mass of inertia, irrespective of temperature, well beyond these limits. Thus inertia also would have to increase with temperature; and when a freely moving mass is becoming warmer its velocity must be diminishing, for its momentum must be conserved. A comet like Halley's is heated upon approach to the sun: thus it should suffer retardation in the approaching, and acceleration

in the receding, part of the orbit, enough, probably, to upset existing astronomical verifications.

Electrodynamic theory does establish unequivocally an increase of inertia of a body arising from gain (SE) of thermal or electric energy; but this is only of amount SE/c^2, where c is the velocity of radiation, and so is minute beyond detection. The question whether there is also an equivalent increase in gravitational mass evades discussion until some link connecting gravitative and electric forces has been established. E. H. B.

862. *The Kata Thermometer as a Measure of the Effect of Atmospheric Conditions upon Bodily Comfort.* **C. E. A. Winslow.** (Science, 43. pp. 716–719, May 19, 1916.)—The readings of an ordinary thermometer afford a poor indication of the degree of comfort felt by the average individual, who in addition to feeling the effects of temperature is also sensitive to air movements. To obtain a more satisfactory measure of comfort L. Hill devised the kata-thermometer outfit, which consists of two thermometers with large bulbs and stems graduated from 86° to 110° F., one to be read as a dry- and the other as a wet-bulb thermometer. The bulbs are heated to about 110° F., and then, while they are freely exposed, the time taken to fall from 100° to 90° is noted. The author has taken three series of readings with the apparatus under different circumstances. At the same time a band of observers estimated the degree of comfort of the conditions on an arbitrary scale of 1 to 5, in which 3 represented ideal conditions and 1 and 5 extremes of cold and warmth respectively. The comparative instrumental and personal results are set out in tables and on a diagram. As a result it seems clear that the instrument is of great value in measuring the actual influence of air conditions upon the body, and is greatly superior to the ordinary thermometer for this purpose. The curves show that conditions of maximum comfort are represented by falling times from 100° to 90° of 45–60 seconds for the wet bulb and 150–180 seconds for the dry bulb.

J. S. Di.

863. *Causes of Volcanism.* **E. Belot.** (Comptes Rendus, 162. pp. 639–641, April 25, 1916.)—Premising that it is generally admitted that volcanism is a phenomenon dependent on fractures usually localised in the neighbourhood of coast lines [Abs. 539 (1915)], an experiment is described to illustrate a suggested method of accounting for the forces exhibited. The principle involved is that in the expansion of water-vapour in deep-seated layers the escaping vapour will follow the isothermal surfaces, which in the neighbourhood of coast lines will generally be inclined upwards towards the shore. The depth of origin will vary, but at 15 km. it is considered that the pressure and temperature may be near the critical temperature of water (364°), and the melting-point of lava (1100°) would be attained some 30 km. lower. When these matrices tend to escape they will follow the isothermal layers, which gradually approach the surface as the depth of water diminishes, until the point of weakness is localised and the eruption of water-vapour and lava takes place. C. P. B.

864. *Transmission of Terrestrial Radiation.* **F. W. Very.** (Am. J. Sci. 41. pp. 513–521, June, 1916.)—Of the outward radiation which leaves the surface of the earth, one part will be absorbed in passing through the air, but another part, which is of such wave-length that the air does not readily absorb it, will escape directly to space. By the term "transmission of terrestrial radiation" is meant the proportion which that part that escapes forms

of the whole. The present author has found this transmission to lie between 26% in summer and 58% in winter, while A. Ångström, on the other hand, states his belief that the transmission for a clear sky is seldom greater than 25% and seldom less than 5%. These divergent views are not so much due to different experimental results as to the different methods adopted for deducing the transmission from the radiation measurements made. A fundamental difference in the theories of the two workers lies in the fact that Ångström deals with the radiation from a point outwards in all directions to the hemisphere of the sky, while Very deems that each element of horizontal surface may be considered as in radiant exchange with the vertical air column of equal section situated directly over it, and considers only, therefore, vertical radiation from each element of the earth's surface. The paper is devoted to a justification of the latter point of view and to an endeavour to point out wherein Ångström's results are in error. J. S. Di.

865. *Causes contributory to Annual Variation of Latitude.* **H. Jeffreys.** (Roy. Astron. Soc., M.N. 76. pp. 499–525, April, 1916.)—The contributions to the annual variation of latitude are considered in so far as they may be due to atmospheric or oceanic motions, snowfall, or vegetation accumulations, the theoretical values derived being plotted in comparison with the observed motions during various periods, and it is concluded that the known meteorological causes are apparently capable of producing the effects observed. With regard to the discrepancies that remain, investigation must be directed to finding a cause that is capable of displacing the pole of inertia at the March equinox in the direction opposite to the Greenwich meridian. C. P. B.

866. *Observations of Latitude Variation.* **E. Przybyllok.** (Astron. Nachr. Nos. 4840, 4841. Observatory, No. 501. pp. 274–275, June, 1916.)—In a discussion of the observations of the International Latitude Service it is pointed out that the assumption of no change occurring during the course of evening observations in the angle between the pole and zenith is improbable. Evidence appears to point to the existence of zenithal refraction, which may not be due to tilting of the atmospheric layers. The phenomenon shows no definite periodicity, and its amount differs at different stations.

It is concluded that the chain method of observation gives an accurate determination of the polar motion, including the z term, but that, on account of the change in the pole and zenith during the observations, the correction to the aberration constant as ordinarily obtained is meaningless. C. P. B.

867. *New Method of discovering Periodicities.* **J. I. Craig.** (Roy. Astron. Soc., M.N. 76. pp. 493–499, April, 1916.)—A method is outlined for the determination of periodicities in any series of observational data, and for the provision of a criterion of the finality of the process. Applied to the sun-spot period the method gives values near 11·5 years, which is nearer Turner's value than the usually accepted figure of 11·125 years. It is pointed out that the theory is adaptable to expressions of a series in terms of any functions defined by linear finite difference or functional equations.

C. P. B.

868. *Longitudes of Jupiter's Satellites.* **W. de Sitter.** (Roy. Astron. Soc., M.N. 76. pp. 448–468, April, 1916.)—Details are given of the results derived from measurements made at Leiden on photographic records of Jupiter's satellites taken at the Cape of Good Hope Observatory during 1913.

The purpose of the investigation is to derive at chosen epochs the longitudes of the three inner satellites for determinations of libration and inequalities. It is shown that it is possible, from a series of plates distributed over a month's time, to derive reliable corrections to the longitudes of the satellites. C. P. B.

869. *Comet or Nebulous Minor Planet.* **M. Wolf.** (Astron. Nachr. Nos. 4841, 4843. Nature, 97. p. 268, May 25, 1916. Abstract.)—A photograph taken at Königstuhl on 1916 April 3, showed a peculiar object, at first designated as a minor planet, 1916 ZK. Three days later it was distinctly nebulous, and this feature became more strongly developed by April 27. On April 30 a nucleus was formed. The object appears to have resembled Neujmin's Comet, 1913*c*, which at first resembled a minor planet. C. P. B.

870. *Comet* 1916*b* (*Wolf*), 1916 *ZK* (*Minor Planet*). **Palisa, Berberich.** (Astron. Nachr. No. 4845, Circ. 508. Nature, 97. pp. 288–289, June 1, 1916. Abstract.)—Later observations of the nebulous object [see preceding Abs.] at Vienna by Palisa showed that the motion was not asteroidal in character. Wolf describes the features of the nebulosity and nucleus as being more cometary than planetary. Provisional elements are given and a short ephemeris. C. P. B.

871. *Selenium Stellar Photometry.* **J. Stebbins.** (Observatory, No. 501. pp. 257–263, June, 1916.)—An account is given of the methods employed and progress made with the selenium photometer in measuring the brightness of stars. The critical condition has generally been in the exact method of annealing the selenium. Estimates of the accuracy attainable are difficult on account of the variability of the cells, but it is thought that with a 12-in. refractor, if two nearly equally bright stars of the second magnitude are near together and culminate near the zenith, a change of 0·1 mag. in one of them would be so conspicuous that it would be detected with three or four exposures on each star. The main disadvantage of selenium is that its manipulation is slow and tedious. Experiments with photoelectric cells have resulted in the production of a photometer at least five or six times as sensitive as was possible with selenium. C. P. B.

872. *Mean Parallax of Stars for Different Magnitudes.* **H. W. Unthank.** (Roy. Astron. Soc., M.N. 76. pp. 529–538, April, 1916.)—An attempt is made to determine, by a least-squares method applied to proper motions, the mean parallax of different groups of stars, each group consisting of stars in a small region of the sky between certain limits of magnitude. The factor governing change of parallax with change of magnitude is given by two separate formulæ as 0·846 and 0·847, which is somewhat larger than the value 0·78 previously given by Kapteyn. The formulæ are not considered suitable for the brightest stars. C. P. B.

873. *Number of Faint Stars with Large Proper Motions.* **F. A. Bellamy** and **J. D. McNeile.** (Roy. Astron. Soc., M.N. 76. pp. 538–542, April, 1916.)—Results are given from the comparison of ten pairs of plates taken with intervals varying from 14·98 to 9·92 years, for the zones + 25°, + 27°, + 29°, in continuation of previous work on the same lines [Abs. 313 (1916)]. In general the limiting magnitude considered is 11·0, but on some plates stars as faint as 13·0 are included. C. P. B.

LIGHT.

874. *Polarised Skylight and the Petrographic Microscope.* **W. S. T. Smith.** (Washington Acad. Sci., J. 6. pp. 229–234, May 4, 1916. Paper read before the Cordilleran Section of the Geolog. Soc. of America, 1913.)—When polarised skylight, reflected from the mirror of a microscope, enters the lower nicol, its plane of vibration may or may not coincide with the plane of vibration of the nicol. In the latter case there is always more or less loss, sometimes amounting to one-half or more of the total illumination received by the microscope. Four possible devices are suggested for remedying this difficulty. (1) Artificial light may be used, or a translucent screen may be interposed between the microscope and direct sunlight. A cloudy sky has the same effect as an interposed screen. (2) The microscope may be so placed that the light will come from a favourable part of the sky. But, while the selection of favourable parts of the sky may somewhat decrease the polarisation effects, it is not always a satisfactory remedy, especially when the choice is restricted to those parts visible from a single window. (3) The microscope may be rotated on its base until the plane of vibration of the reflected polarised skylight coincides with that of the lower nicol of the instrument. When the observer can move with the microscrope this method is entirely satisfactory. (4) A suitable compensator introduced below the polariser, and capable of independent rotation about the axis of the instrument, may effect practically complete correction of the polarisation, and at the same time give a whiter light. A simple type of such compensator is a half-wave plate cut from quartz or muscovite. If this is used, however, with a microscope in which both nicols can be rotated simultaneously, it is necessary to connect the mounting of the compensator with that of the polariser so that when the polariser is turned through any angle the compensator will be rotated through half that angle in the same direction. A. W.

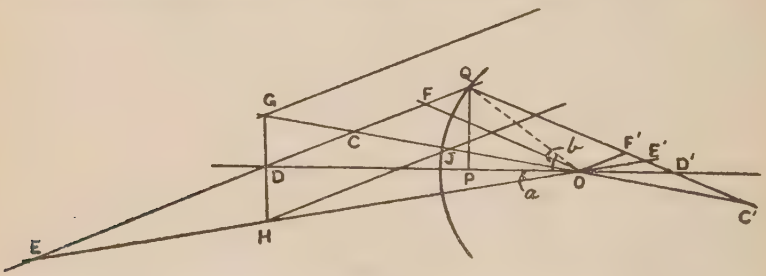
875. *Lenses for Light Distribution.* **T. Smith.** (Phys. Soc., Proc. 28. pp. 211–219; Disc., 219, June, 1916. From the National Physical Laboratory.)—The principle on which lenses for securing a required distribution of light from a given source have been designed is illustrated by a two-dimensional example. The principle employed is to divide the incident and emergent energy into a number of equal parts, and compute the lens system so that the rays which separate off these portions of incident light from one another are refracted as rays which separate the corresponding portions of the emergent light. The surfaces obtained are in general of varying curvature, and the lenses must, therefore, be moulded. It is shown how the effect of the finite size of the light source may be determined. AUTHOR.

876. *Choice of Glass for Cemented Objectives.* **T. Smith.** (Phys. Soc., Proc. 28. pp. 220–234, June, 1916. From the National Physical Laboratory.) —The strict fulfilment of the mathematical conditions for freedom from colour, spherical aberration and coma, for objects at varying distances from a thin cemented doublet lens, necessarily demands a change in the kinds of glass as the position of the object is changed. The author describes a method by which the proper glasses can be determined by using a glass chart on

translucent paper, in conjunction with diagrams calculated for the purpose, as a slide-rule. With most glasses the solution to the problem is imaginary, and formulæ are given for calculating the boundary separating real and imaginary solutions by solving a quadratic equation. In practice it is found that the curves for all real images lie very close to one another. Notwithstanding this, a numerical example shows that there will be a perceptible difference in the definition obtained if in place of the theoretically necessary type a kind of glass is substituted which does not differ greatly from the other, and lies on a curve giving perfect correction for another real magnification. It is further shown that when no real solution is forthcoming for a double lens a real solution will in practice be obtained by adopting a triple objective made of the same glasses. AUTHOR.

877. *Correction of Chromatic Aberrations when the External Media are Dispersive.* **T. Smith.** (Phys. Soc., Proc. 28. pp. 235–241, June, 1916. From the National Physical Lab.)—The best way of correcting can be determined from the expressions given by the author on taking into consideration the range of magnifications for which the system is to be used and the relative magnitudes of the field of view and the angular aperture. L. H. W.

878. *New Fundamental Equation in Optics.* **C. W. Woodworth.** (Science, 43. pp. 824–825, June 9, 1916.)—Develops a new and accurate equation for the position of conjugate foci of spherical lenses. Measurements are made from the centre of curvature instead of from the surface of the lens, and this leads to the following accurate equation: $n/f + n'/f' = [(n - n')/r](\cos a/\cos b)$, where n and n' are the indices of refraction, f and f' the focal distances of conjugate foci, r is the radius of the lens, a the focal angle, and b the radial angle. The meaning of these terms will be seen from



the Fig. [which has been drawn from the description given in the paper, since no figure is there reproduced]. E, E′ are the conjugate foci, EQE′ is the path of the ray, O the centre of the lens, and DOD′ a line through O. Then in the above equation OE $= f$, OE′ $= f'$, OQ $= r$, angle EOD $= a$, and angle QOD $= b$. The remainder of the Fig. is for the purposes of the proof, for which the original paper should be consulted. J. W. T. W.

879. *Use of the Auto-collimating Telescope in the Measurement of Angles.* **J. Guild.** (Phys. Soc., Proc. 28. pp. 242–249; Disc., 249, June, 1916. From the National Physical Lab.)—The measurement of angles by means of the autocollimator resolves itself into the measurement of the distance between two images produced in the focal plane of a micrometer eyepiece. In most cases the light forming these images passes through portions of the object glass on opposite sides of a diameter. It is shown that, when this diameter is

perpendicular to the direction of the displacement to be measured, uncertainty and error are introduced on account of any residual spherical aberration of the object glass and the depth of focus of the telescope. One or two particular cases are discussed in which it is shown how this may be obviated. AUTHOR.

880. *Flicker Frequency as affected by Colour.* **L. T. Troland.** (Frank. Inst., J. 181. pp. 853–855, June, 1916.)—The frequency at which flicker due to difference in colour, as distinct from difference in brightness, can just be made to disappear, depends chiefly on the difference in hue of the sources compared. The author determines the frequency for the various spectrum colours compared with a white standard (tungsten lamp). The tests were carried out with illumination-values of 1025 and 547 photons respectively. (One "photon" is defined as the illumination of the retina corresponding with a stimulus-surface brightness of 1 candle per sq. metre, and an effective pupillary area of 1 mm.^{2}.) The frequencies (cycles per sec.) thus determined are assembled in tabular form. The lowest frequencies occur in the yellow (15·94–17·1), the highest in the red (24·49–27·76). The photometric sensibility also varies between wide limits according to the difference in colour of light from standard and comparison source, the range of observations being greatest (4·45–6·39 %) when red light was compared with the light from a somewhat overrun tungsten lamp. J. S. D.

881. *The Clustering-tendency of the Molecules in the Critical State and the Extinction of Light caused thereby.* **F. Zernike.** (K. Akad. Amsterdam, Proc. 18. pp. 1520–1527, 1916.)—In a previous paper an improved formula was derived for the scattering of light by a single substance in the neighbourhood of the critical point. In that paper the inaccuracy of former approximate formulæ, which gave an infinitely strong scattering for the critical state, had been corrected by exactly taking into account the influence of the arrangement of the molecules in space, after a new probability-method. In fact, the intensity of the scattered light could be given for the critical point itself. The former difficulty, however, has not quite disappeared in that way, for when the total scattered energy is computed from the given formula in order to find the extinction of the incident light, then a logarithmic expression arises which still becomes infinite in the critical point. A better approximation is of practical importance, since it has been shown that the magnitude of the sphere of attraction might experimentally be found from measurements of the opalescence, consequently a theoretically accurate formula for the extinction is most urgent. In the present paper a better value for the extinction is found by deriving it directly from the theory of electrons. For this purpose it has been necessary first to calculate explicitly a formerly introduced function which indicated the course of the mean density of the molecular clusters, and this constitutes the first portion of the paper. Following come the electronic considerations, which are an extension of the treatment given by Lorentz for the scattering of light by an ideal gas. H. H. Ho.

882. *Diffraction-ring Pattern in the Shadow of a Circular Object.* **M. E. Hufford.** (Phys. Rev. 7. pp. 545–550, May, 1916.)—The author has obtained photographs of diffraction-ring patterns by use of circular openings and steel spheres containing as many as 25 rings representing minima of intensity [Abstract No. 1540 (1914)]. Lommel has deduced formulæ for calculating the radii of these rings and has compared the calculated and measured values

for a few of them. In the present work the radii of many more are measured and compared with approximate theoretical values obtained by using Lommel's expression. T. H.

883. *Optical Activity of Liquids and Gases.* **F. Gray.** (Phys. Rev. 7. pp. 472–488, April, 1916.)—The present study of optical activity was undertaken because of the difference between the chemical and physical view-point concerning the natural activity of isotropic substances. On the chemical side Pasteur, Le Bel, and van't Hoff developed the present conception of molecular structure and proposed the theory connecting optical activity with an asymmetric structure of the molecule. By physics the subject has been treated more from the optical side, and Drude and Voigt have shown just what form of electromagnetic equations must hold in an active medium in order to produce rotation. The two theories have not yet been tied together, and it has not yet been shown why the asymmetric molecule should give rise to these particular equations.

The paper consists of two parts, the first being a brief report of a theoretical study of a few types of molecules which has led to a very natural and satisfactory explanation of both the chemical and the physical facts of optical activity, while the second is a report of an experimental search for phenomena predicted from the theory. Drude has shown that the modified field equations would result if the paths of some of the electrons in an active medium were short helices all twisted in the same direction and with axes oriented at random in space, but he made no attempt to show how the asymmetric structure of the molecule causes these spiral tracks, and thus his theory does not tie up with molecular structure, nor does it account for the anomalous rotary dispersion of the metallic tartrates. For this reason the author has made a study of the interaction between atoms in the hope that such interactions might afford a more satisfactory explanation of optical activity. The case of a molecule with 5 atoms is first considered, the assumption being made that the atoms are small compared to the distances between them, so admitting of being treated as electric doublets. The method is then extended to include other molecules. Assuming that the atoms of a molecule may be electrically polarised by a light wave and that they then interact according to the ordinary laws for an electric doublet, it is shown that the optical activity of isotropic substances may be explained as a result of such interactions. From this view-point an asymmetric molecule will be active and a symmetrical molecule inactive. A molecule must have more than three atoms to be active. A connection has been shown between molecular activity and atomic refractivity, and the reason for the failure of the Guye hypothesis in so many cases is demonstrated. The latter states that the optical activity of a molecule is measured by its mass asymmetry, but from the present theory it is not the mass asymmetry which is important, but the asymmetry in terms of atomic or group refractions. A possible explanation of the variation of rotation with temperature has been given. According to the present view of activity any absorption band belonging to an active molecule might cause anomalous rotation. The work of Tuchugoff and Ogordnikoff supports such a view. An experimental test was made for the most extreme case that could be obtained. A neodymium atom was introduced into an active molecule and the rotation was found to be anomalous at the bands characteristic of the atom—a result in support of the author's theory. A monochromatic illuminator with a divided field was used, it being impossible to use the quartz wedge

method. Experimental details with diagrams are given. A footnote refers to Stark and Born's recent articles on the same subject, in which the suggestion is made that natural activity might be explained as the result of the interaction of doublets. The author's method may be regarded as a special case of Born's more general theory with two important differences: (1) Born views a molecule as a system of coupled electrons, the coupling and restoring forces being identical, whereas the present author regards the atom as a particle of dielectric; the atoms are coupled according to the ordinary laws for a doublet, and the restoring force on an electron is not identical with the coupling, but may be influenced by it. This is supported by the fact that many absorption bands are roughly characteristic of the atom, and that for many organic compounds the refractive index is an almost additive property. (2) Born neglected the retardation of the interaction between particles.

H. H. Ho.

884. *Circular Polarisation produced by Spherolites.* **P. Gaubert.** (Comptes Rendus, 162. pp. 764–766, May 15, 1916.)—Circular polarisation is produced under the following conditions:—(*a*) When a liquid crystal passes from a monorefracting to a negatively birefracting condition (cholesterol propionate, benzoate, &c.) unstable spherolites of diameter less than 0·01 mm. are produced which give a blue reflected light and a red transmitted light, the latter being circularly polarised. (*b*) Cholesterol caprinate containing 1/5 of diphenylamine gives solid spherolites producing circular polarisation. (*c*) Films of cholesterol quickly cooled on a microscope slide, especially in presence of 1/25 of anisaldazine, give minute spherolites 0·004 to 0·02 mm. diameter, and furnish a very large proportion of circularly-polarised transmitted light.

T. M. L.

885. *Constants of the Quartz-wedge Saccharimeter and the Specific Rotation of Sucrose.* **F. Bates** and **R. F. Jackson.** (Bureau of Standards, Bull. 13. pp. 67–128, 1916. [Sci. Papers, No. 268.])—The investigation was undertaken because the 100° sugar point of the saccharimeter is one of the most important and fundamental constants both from a commercial and scientific view-point, and also because the Bureau had long found it impossible to make a pure sugar test 100 % on modern polariscopes. The preparation of pure sugar by special vacuum apparatus eliminated the necessity of heating above room temperature. The 100° sugar point was found to be over one-tenth per cent. too high, this making the test of all sugars too low by that amount. The producers of sugar, as well as the U.S. Government in the collection of duty have, owing to this, lost very large sums of money.

L. H. W.

886. *Magnetic Rotary Dispersion in Relation to the Electron Theory.* III. *Number of Electrons and Additive Relations.* **S. S. Richardson.** (Phil. Mag. 31. pp. 454-478, May, 1916.)—The application of magnetic rotary dispersion to the determination of the number of resonators present in the molecule of a substance is here considered. If N denotes the number of resonators present in the unit of volume, p the number per molecule, m the mass and e the charge of each, d the density and M the molecular weight of the substance, and h the absolute mass of the hydrogen atom, $N_1e_1 = p_1de_1/Mh$. If attention be confined to electrons, the ratio of e_1 to h is equivalent to the electrolytic constant, 96,530 coulombs or $9653 \times 3 \times 10^{10}$ e.s. units per gm. When N_1e_1 can be obtained from optical

data, the above equation gives at once the value of p_1. Methods are shown for deducing the number of electrons (1) from natural dispersion and (2) from magnetic rotation. Comparison of the values of v and p for various typical organic compounds shows that probably in every case the number of electrons influencing the refraction is not greater than the total number of normal valencies of the atoms. The author develops a theory of magnetic rotary dispersion of organic compounds according to which the summation is referred not to the atoms alone or to the valency linkages alone, but to the two combined. It is claimed that this theory (1) contains internal evidence of its truth, (2) leads to values admitting of a more rational interpretation than those of the "atomic" method, and (3) correlates the phenomena of magnetic rotation and refraction. Values are deduced for the atomic refractions of carbon, hydrogen, and oxygen, and for the refractions corresponding with the linkings (CC), (CH), (CO), (OH), etc., and the summations of these for a number of organic compounds give moderately good agreement with the experimental values in all cases. T. H. P.

887. *Wave-length Standards in the Iron Spectrum.* **K. Burns, W. F. Meggers,** and **P. W. Merrill.** (Bureau of Standards, Bull. 13. pp. 245–272, 1916. [Sci. Papers, No. 274.])—Between the limits 3233 Å. and 6750 Å. some 400 lines were either remeasured or measured for the first time by the interference method. The work was done in conformity with the recommendation of the International Wave-length Committee. Where it was found possible, faint lines as well as strong ones were measured. Satisfactory standards were found at intervals of 10 or 15 Å.U. throughout the greater part of the spectrum ; there are no sharp iron lines of even moderate intensity in the region 5775 to 5934 Å., and the number is insufficient in the extreme red. The spectroscope used was a 635-cm. concave grating mounted in parallel light. The greater part of the wave-lengths were measured by three interferometers, the order of interference ranging from 20,000 to 50,000 in the case of each line. The method was that of Buisson and Fabry. The mean difference between the present observations and the I.Å. standards is about 1 in 4×10^6. It is thought that some of the standards are in error by 0·002 Å. or more. Interferometer observations under the conditions described were found to be reasonably free from pole-shifts. Comparison with all the grating observations which have been made on the I.Å. system shows, as has been found before, that more numerous secondary standards are needed in order to obtain the highest accuracy in grating work. While grating observations often show an intensity equation, interference measurements appear to be reasonably free from this effect. The sharpness of over 600 lines was determined, and the data were correlated with data relating to pole-shifts, to behaviour under pressure, and to intensity. Lines showing a negative pole-shift are never very sharp, while those having a positive pole-shift are sometimes perfectly sharp in the centre of the arc ; the lines subject to a shift are more likely than are the unaffected lines to be broad, even in the centre of the arc. Lines which are faint or of only moderate intensity are sharper on the average than strong lines. Still, some very strong lines are quite sharp. The width of the average line, expressed as a proportion of the wave-number, is not a function of the wave-length. All the results are tabulated. [See also Abs. 550 (1915), 65 and 68 (1916).] A. W.

888. *Series Lines of Hydrogen.* **W. Wien.** (Ann. d. Physik, 49. 7. pp. 842–850, May 11, 1916.)—A paper dealing with the electrodynamic separa-

tion of the series lines of hydrogen. Soon after Stark's discovery of the electric separation of the hydrogen lines, Wien showed, from reasoning based on the electromagnetic theory, that this effect should also occur in a magnetic field if the luminous particles move with a sufficiently great velocity. Hydrogen canal-rays have a velocity of about 10^8 cm./sec., and experiments here described exhibit the effect quite plainly. Since, however, the canal-rays move with different velocities, no sharp lines are obtained under the influence of a magnetic field, but there is an unmistakable broadening of the lines seen in the absence of the field. The electric force can in general be divided into two parts according to the equation $F = (1/c)(E + vH)$, where E is the electrostatic, H the magnetic field, both in electromagnetic units, v is the velocity of the particles and c the velocity of light; so E can be replaced by vH if this latter product is made great enough. A full description is given of the apparatus used, and a number of photographs are reproduced. The following table gives the results of some of the measurements :—

Line.	Discharge Potential, Volts.	Maximum v.	vH.	Breadths of Lines.			
				Outer Components.		Inner Components.	
				Calculated.	Observed.	Calculated.	Observed.
H_γ	5000	$6{\cdot}5 \times 10^7$	$11{,}000 \times 10^8$	4·4 Å.	3·9 Å.	3·2 Å.	2·8 Å.
	5000	6·5 „	11,000 „	4·4	5·0	—	—
	8200	5·2 „	8800 „	3·5	4·2	2·6	2·3
	8200	6·6 „	11,200 „	4·5	4·8	3·3	3·7
	14,500	7·7 „	13,100 „	5·2	6·2	3·8	4·8
H_β	5000	6·8 „	11,600 „	3·2	4·3	—	—
	8200	6·4 „	10,900 „	3·0	4·2	—	—
	14,500	7·7 „	13,100 „	3·6	4·8	—	—

A. W.

889. *Emission Spectra in Ultra-red.* **W. Mandersloot.** (Ann. d. Physik, 49. 6. pp. 725–730, May 5, 1916.)—A theoretical treatment relating to gases with diatomic molecules. It is assumed, from considerations based on the classical theory, that for mean and for higher temperatures the law of equipartition of energy holds for the translation and rotation of gas molecules. It is then shown that in the spectrum of the rotating dipole, the translation has practically no effect. A calculation is made of the wave-lengths for max. intensity and the numbers obtained for HCl, HBr, and CO are compared with the results obtained by Eva v. Bahr. A. W.

890. *Infra-red and Ultra-violet Absorptions of Sulphur Dioxide and their Relation to the Infra-red Spectra of Oxygen and Hydrogen Sulphide.* **C. S. Garrett.** (Phil. Mag. 31. pp. 505–511, June, 1916.)—A detailed study has been made of the gaseous absorption of SO_2 in order to test the applicability of Baly's theory of the connection between ultra-violet and infra-red absorption. The broad absorption band exhibited by SO_2 in the liquid and solution phases becomes resolved into a number of small band groups which, at any rate in the less refrangible ultra-violet region, are symmetrically distributed round a central band group of max. absorption. By varying the pressure

and thickness of the absorption layer of the gas at constant temperature, the whole of the complex absorption has been traced and the molecular extinction coefficient for each component band group determined. Series of constant frequency-differences are found to occur between the centres of the band groups, and by averaging these differences their real values have been ascertained with considerable accuracy. Further, the whole region of absorption can be divided into three portions, namely: a less refrangible portion in which the average difference between the wave-numbers of the centres of the consecutive bands is 22·4, an extreme ultra-violet region where this difference is about 35, and an intermediate region where combinations of these differences occur together with a third difference of about 12. The whole absorption region consists apparently of two principal band groups, the centres lying near $\lambda = 2960$ and beyond $\lambda = 2107$ respectively. As regards the less refrangible band, the trace of the absorption curve shows that the true optical centre lies at $\lambda\,2961$ or $1/\lambda = 3378$. According to Baly's theory the latter should be an even multiple of a fundamental band in the short-wave infra-red region; since Coblentz found the most pronounced band between $3\,\mu$ and $11\,\mu$ to lie at $\lambda = 7{\cdot}4\,\mu$ or $1/\lambda = 135{\cdot}1$ and $135{\cdot}1 \times 25 = 3377{\cdot}5$ Baly's theory is supported. Baly's further postulate, that the constant differences in the wave-numbers in the ultra-volet are compounded from certain basic constants characteristic of the molecule, and that these basic constants determine the infra-red absorption of the molecule, also finds confirmation in the experimental numbers. The wave-number difference, 34·4, characteristic of the extreme ultra-violet region of absorption of SO_2 is found to be derived from the specific sulphur bases, and the conclusion is drawn that it is the sulphur atom of SO_2 which is mainly responsible for the production of this second ultra-violet band group, of which only a portion has been observed on account of the limited transparency of quartz. Similar reasoning indicates that the oxygen atoms in the molecule must be the chief determining cause of the typical band system characteristic of the first absorption band group in the near ultra-violet region. T. H. P.

891. *Ultra-violet Absorption System of Sulphur Dioxide.* **E. C. C. Baly** and **C. S. Garrett.** (Phil. Mag. 31. pp. 512–520, June, 1916.)—The authors deal further with the results obtained by Garrett [see preceding Abs.]. The wave-number of the most important absorption band in the short-wave infra-red region of SO_2 is given by $33751{\cdot}6/25 = 1350{\cdot}06$, corresponding with a wave-length of $7{\cdot}407\,\mu$. Again, the least common multiple of the basic constants is given by $1350{\cdot}06/14 = 96{\cdot}433$, and the wave-numbers of the infra-red absorption bands are multiples of this least common multiple. The general formula expressing the whole system of lines in the ultra-violet band group is, $33751{\cdot}6 + p \times 223{\cdot}225 + n \times 273$, where $p = -7, -6, \ldots 0 \ldots +12, +13$, and $n = -44, -43, \ldots 0 \ldots +36, +37$. The whole band group consists, therefore, of 21 sub-groups each containing 82 absorption lines; the wave-numbers of these 1722 lines have been calculated and arranged in the 82 series of constant difference and compared with Miss Lowater's observed values [Abs. 1239 (1910)] after reducing the latter to a vacuum. The good agreement between the observed and calculated values supports the validity of the formula.

The results obtained entirely support the theory of the relation between infra-red and ultra-violet absorption, and there is little doubt attaching to the formula given above for the less refrangible ultra-violet absorption band of SO_2. T. H. P.

892. *Lo Surdo's Law.* **C. Sonaglia.** (Accad. Lincei, Atti, 24. p. 621, 1915. N. Cimento, 11. pp. 207–211, March–April, 1916.)—The series given by Lo Surdo [Abs. 1059 (1914)] may be extended to the fifth line of Balmer's series as follows: Line, H_ϵ; λ, 3970·3; n, 7; total number of components, 7; order of line in series, 5; components with normal vibrations, 5. T. H. P.

893. *Hydrogen Canal Rays.* **R. v. Hirsch.** (Ann. d. Physik, 49. 7. pp. 851–864, May 11, 1916.)—Describes research on the light emission by hydrogen canal-rays. It is shown that there is no appreciable pressure effect on the intensity ratio of the displaced and stationary lines. The effect of the magnetic field on the intensity ratios $H_\alpha : H_\beta$ and $H_\alpha : H_\gamma$ is illustrated graphically, and the results are discussed. It is concluded that the hydrogen canal-rays emit light on becoming charged, that is, by gaining or losing an electron, while the ionisation and neutralisation light is closely connected with the impact of the displaced on the stationary particles; hence the greater intensity of the stationary line and the stronger polarisation. A. W.

894. *Extremely Penetrating Radiations of the K-series of Tungsten, and the X-ray Spectra of Heavy Metals.* **de Broglie.** (Comptes Rendus, 160. pp. 596–597, April 17, 1916.)—With the increasing use of Coolidge tubes the author gives a few results which are of interest to users of this tube. The observations prove the existence of a group of rays of extremely high frequency which correspond to the K-radiation of tungsten. This group comprises:—

Rays.	"Selective Angle" from NaCl.	Wave-length.
α_K	2° 04′	$2{\cdot}032 \times 10^{-9}$ cm.
β_K	1° 48′	$1{\cdot}768 \times 10^{-9}$ cm.

The "ray" α is a doublet of which the components are separated by an angle of about 2′. These extremely penetrating X-rays may be classed in the same spectral region as the penetrating γ-rays from RaB. They are produced when the p.d. reaches 75,000 volts.

An examination has also been made of the X-ray spectra (by an analysis of secondary X-rays) of the heavy metals Th and Ur. Similar observations on Hg, Tl, Pb, and Bi have been published previously [Abs. 1837, 1838 (1914)]. For Th and Ur, the rays noted are:—

Thorium (oxide) ..... 7° 47′ (strong), 8° 03′, 9° 44′ (double),
Uranium (oxide) ..... 7° 22′, 7° 43′, 9° 18′,

which give, by Moseley's law, the atomic numbers 90 and 92 for these elements. A. B. W.

895. *Symmetry of Röntgen Patterns of Triclinic and some Rhombic Crystals. Remarks on the Diffraction-images of Quartz.* **H. Haga** and **F. M. Jaeger.** (K. Akad. Amsterdam, Proc. 18. pp. 1552–1556, 1916.)—The results contained in this paper are given as a sequel to previous studies of a similar nature. Röntgenograms of the following triclinic crystals are reproduced: Copper sulphate ($+5H_2O$), diaspore, potassium dichromate, olivine, bronzite, lithium sulphate, quartz, brucite, antimonite. Stereographical projections are also shown for the same crystals. The observations support the general conclusions drawn in a previous paper. [See Abs. 686 (1916).] A. B. W.

HEAT.

896. *A Morse Optical Pyrometer adapted to a Wide Range of Laboratory Uses.* **W. E. Forsythe.** (Astrophys. J. 43. pp. 295–301, May, 1916.)—The author describes various mechanical improvements. The telescope is in two parts, connected by a U-shaped frame mounted on a stand somewhat similar to a spectroscope. The pyrometer lamp is carried in a special holder giving universal motion. Immediately in front of the lamp provision is made for the insertion of a rotating sector for reducing the intensity of the incident radiation by a definite amount. The tube holding the objective lens is built up in sections, an arrangement which permits of a magnification from a little more than twice to a focus for parallel light. Thus it is possible to measure the brightness of either a distant object or of a lamp filament of diam. 0·1 mm. The pyrometer lamps are specially made with a slight bend in the centre of the filament, in order to enable the observer always to match with the same portion of the filament. E. G.

897. *Thermal Expansion of Tungsten at Incandescent Temperatures.* **A. G. Worthing.** (Frank. Inst., J. 181. p. 857, June, 1916.)—Measurements of change in length with temperature were made on straight tungsten filaments of large cross-section. The positions selected on the filaments were sufficiently removed from the leading-in wires to ensure that the cooling effects were negligible. Using the temperature scale previously determined [see Abs. 576 (1916)] it was found that for the region 1200° K. to 2700° K. the following relation holds :—

$$(L - L_{800})/L_{800} = 4{\cdot}49 \times 10^{-6}(T - 300) + 2{\cdot}4 \times 10^{-13}(T - 300)^3,$$

where L is the length at temperature T and L_{800} the length at 300° K. The formula represents also the single value at room temperature (300° K.). The region between room temperature and 1200° K. is to be included in the final publication. J. W. T. W.

898. *Heat Losses from Incandescent Filaments in Air.* **L. W. Hartman.** (Phys. Rev. 7. pp. 431–441, April, 1916.)—Describes a new determination of the conduction and convection losses of filaments of platinum sponge between the [black-body] temperatures 700° and 1700° C. These temperatures were measured by matching the brightness of the filament with that of a piece of magnesium oxide enclosed in an electric furnace the temperature of which was measured both thermoelectrically and by means of a Wanner pyrometer. The radiated power was then calculated from the Stefan-Boltzmann law, using Coblentz's value of σ, viz. 5·61, and the difference between this and the power supplied gave the sum of the conduction and convection losses. This sum is approximately proportional, per cm. of wire, to the absolute temperature between the range 900° to 1700° abs. In order to separate the two losses, experiments were made on wires enclosed in vacuum vessels. The difference between the total energy-loss and the sum of the radiation and conduction losses thus determined was taken as the conduction loss. From these data, by applying the method of least squares it is possible to compute the constants A and B in Lorenz's formula for the energy losses from a radiator in air, viz. $E = A(T^4 - T_0^4) + B(T - T_0)^{5/4}$. J. W. T. W.

899. *Relation between Colour Temperature, Apparent Temperature, True Temperature, and Monochromatic Emissivity of Radiators.* **P. D. Foote.** (Washington Acad. Sci., J. 6. pp. 317–323, June 4, 1916.)—Forms a continuation of an earlier paper [see Abs. 703 (1916)]. It is found possible to represent the emissivity of metals for wave-lengths in the visible spectrum and over a moderate temperature-range by the expression $A'e^{(c_2 p/\lambda)}e^{(q/T)}$, where A', c_2, p, and q are constants and T is the absolute true temperature. If the emissivity is constant with wave-length as in a grey body, then $p = 0$. Variations in the emissivity with temperature are accounted for by adjusting q. It is shown that at the temperature (T′) of colour-match between a black body and a non-black body (colour temperature of the non-black body) $1/T' = (1/T) - p$. Further it is shown that if S be the apparent temperature of the non-black body for a wave-length λ, then if $(1/S - 1/T')$ be plotted against $1/T'$ the resulting curve is rectilinear and of slope $-\lambda q/c_2$, so that the easily measured quantities S and T′ may be used to determine q and so give the temperature coefficient of emissivity (see expression given above for the emissivity). The values obtained by Hyde, Cady, and Forsythe [see Abs. 558 (1916)] for carbon give $q = +462$. For tungsten the values given by the same experimenters lead to the following expression for the emissivity :—$A = 0{\cdot}304e^{(0{\cdot}1492/\lambda)}e^{(322/T)}$, where λ is in microns, and $1/T = 1/T' - 0{\cdot}0000104$. The agreement between the computed and observed values of T′ is remarkably good. From the above expression the emissivity of tungsten at temperatures between 1700° and 2400° abs. and for wave-lengths between 0·7 μ and 0·4 μ have been calculated and are tabulated in the paper. For platinum, Waidner and Burgess' values of the emissivity at the melting-point [see Abs. 2024 (1906)] gives $p = 0{\cdot}0000185$. This makes the colour-temperature of Pt at the melting-point some 80° higher than the true temperature. J. W. T. W.

900. *Luminosity and Temperature of Metals.* **P. D. Foote.** (Washington Acad. Sci., J. 6. pp. 323–326, June 4, 1916.)—In a previous paper [see Abs. 702 (1916)] it was shown that the luminosity of a black body is given by $L = P(\theta + B)^D(\theta + C)^{-D}$. Assuming that the emissivity of a non-black body can be represented as in the preceding abstract, it is easily shown that the luminosity of such a body at temperature θ is given by $L' = A'e^{(q'\theta)}P(\theta' + B)^D(\theta' + C)^{-D}$, where $(1/\theta') = (1/\theta) - p$. From Hyde, Cady, and Forsythe's determination of the brightness of a black body at various temperatures [see Abs. 558 (1916)] it is found that $P \times 10^{-7} = 1{\cdot}91$, while their data for colour temperature, true temperature, and apparent temperature of tungsten give $A' = 0{\cdot}303$. Using these values, Langmuir's determination of 6994 candles per cm.^{2} for tungsten at the melting-point gives a temperature of 3712° abs. If Langmuir's values for the emissivity are used, the melting-point is found to be 3660° abs. J. W. T. W.

901. *Selective Radiation from Osmium Filaments.* **E. F. Barker.** (Phys. Rev. 7. pp. 451–471, April, 1916.)—Describes an investigation to determine whether or not the osmium filament exhibits a temperature variation of selectivity. Photometric measurements were made on three glow-lamps with osmium filaments, and the following equations derived for the variations with voltage of the watts consumed and the candle-power radiated : $W = 0{\cdot}026609\,V^2 - 1{\cdot}65072\,V$, where $V = \log$ (volt ratio), and $W =$ corresponding log (watt ratio) ; and $C = -1{\cdot}24490\,V^2 - 3{\cdot}91898\,V$, where $V =$ log (volt ratio) and $C =$ log. of corresponding candle-power ratio. A comparison

of the luminous efficiencies of osmium and carbon lamps at colour-match voltages shows that osmium is a highly selective radiator, while the application of Hyde's criterion for the detection of variations of emissivity [see Abs. 1852 (1912)] shows that the emissivity is a function of both wave-length and temperature. A method is described for the determination of the relative shapes of the energy curves for two filaments when the best possible colour-match has been obtained, and the colour ratios computed under various conditions indicate that, when the extremes are matched, the curve for osmium is somewhat depressed relative to that for carbon in the middle portion of the visible spectrum. Energy curves for both radiators have been obtained in the infra-red region out to wave-lengths of $2{\cdot}4\,\mu$, and the observations show that the two cannot be brought into coincidence at any voltage. Here again are marked changes of emissivity with temperature. The relations of the energy curves in the infra-red at voltages corresponding to a colour-match in the visible spectrum show that the osmium radiation is very noticeably deficient in energy of the longer wave-lengths. It is shown that, whereas with carbon the rate of increase of intensity with temperature increases from the longer towards the shorter wave-lengths, in the case of osmium, on the other hand, the rate of increase in the neighbourhood of $2{\cdot}4\,\mu$ is greater than for wave-lengths $2{\cdot}098\,\mu$ or $1{\cdot}750\,\mu$. It is suggested that this effect may indicate the presence of an emission band. J. W. T. W.

902. *The Latent Heat of Fusion of a Metal and the Quantum Theory.* **H. S. Allen.** (Phys. Soc., Proc. 28. pp. 204–209; Disc., 209–210, June, 1916.)—The latent heat of fusion is identified with the energy necessary to counterbalance that of a certain number of "oscillators" concerned in holding together the crystalline structure. Assuming that the energy of an oscillator having a vibration frequency ν is $\mathrm{RT}[x/(e^x-1)]$, where x stands for $h\nu/\mathrm{RT}$, it is found that the atomic heat of fusion of a metal can be calculated with fair accuracy by the formula, $\mathrm{AL}=c\mathrm{NRT}[x/(e^x-1)]$. Here A denotes the atomic weight, L the latent heat, and c the ratio of the number of oscillators in question to the number of atoms. Thus, the number of oscillators in 1 gm.-molecule is Nc, where N is Avogadro's constant. It is found that to the factor c must be assigned a value which is either unity or a simple fraction. The frequency at the temperature of the melting-point is calculated by means of the formula of Lindemann. The application of Debye's theory is also discussed. Author.

903. *Examples of the Application of the Method of Closed Cycles.* **E. Bouty.** (Journ. de Physique, 4. pp. 761–769, Dec., 1914.)—The method of closed cycles is being abandoned more and more in the application of the principles of thermodynamics to any given system, recourse being made to analytical methods involving internal energy and entropy. From the pedagogic standpoint, however, the geometric method of cycles has the advantage of affording better illustration of the reality of physical processes, while being more intuitive and often the means of bringing about the desired result more rapidly. The object of the present paper is to illustrate this latter view-point by suitable examples, and the author makes no claim to originality. The cases chosen include the specific heats of a saturated fluid, equilibria in homogeneous gas mixtures, and quantities of heat. An interesting case is that of water-vapour, which between 0° C. and 100° C. is usually regarded as being comparable with a perfect gas. The author shows that in the immediate neighbourhood of liquefaction, water-vapour may only be

very approximately compared to a perfect gas. Throughout the paper the author makes use of the lemma, that, when a closed cycle comprises isothermal operations executed upon perfect gases, it is allowable to abstract these operations when applying the principle of equivalence, since in them the quantities of heat involved and the work done are exactly equivalent, the internal energy being invariable. H. H. Ho.

904. *Equation of State for Air, tested by Measurements of the Ratio between the Specific Heats and of the Specific Heats themselves.* **F. A. Schulze.** (Ann. d. Physik, 49. 5. pp. 569–584, April 11, 1916.)—The values of $\chi = c_p/c_v$ for air, obtained experimentally by Koch [Abs. 1280 (1908)], from the velocities of sound at different temperatures and the isotherms are compared with the values calculated from the van der Waals equation of state. At 0° the agreement between observation and experiment is very good throughout the whole region of pressure up to 200 atmos. The deviations increase with the pressure, the max. value being just over 2 % at 200 atmos. For −79·3° the agreement is also good at moderate pressures, the divergence being 1–2 % at 100 atmos.; at higher pressures the difference increases rapidly with the pressure and at 200 atmos. amounts to 18 %. The principal cause of the divergences is the variability of β, the ratio of the intramolecular to the progressive energy.

From the results of Koch's measurements the equation of state, $(p + a/\theta^n v^2)/(v - b) = R\theta$, is derived for air, the values of a, b, and n being 0·01278, 0·00136, and 0·348 respectively; with Berthelot's simple equation, in which $n = 1$, Koch's experimental numbers are not in agreement. Further, the above equation is in good accord with Holborn and Schultze's recent measurements of the isotherms of air for 0°, 50°, 100°, 150°, and 200° up to about 100 atmos. [Abs. 92 (1916)].

From the equations $\left(\frac{\partial c_v}{\partial v}\right)_\theta = \theta \frac{\partial^2 p}{\partial \theta^2}$ and $p = R\theta/(v - b) - a/\theta^n v^2$, a formula is derived for χ which gives numbers in satisfactory agreement with the experimental values.

The equation of state for air given above is shown to be in accord with the values obtained by Holborn and Jakob for c_p at 59° and pressures of 1–200 atmos. [Abs. 866 (1915)] but not with the results of Joly's investigations on the dependency of c_v on the volume (Phil. Trans., 128A, p. 73, 1891), which scarcely indicate any increase of c_v with the pressure, owing mainly to their large probable error. In the case of CO_2, however, Joly's observations on the variation of c_v with the pressure are in good agreement with theory. T. H. P.

905. *Inversion Curves of the Joule-Thomson Effect for Air.* **F. A. Schulze.** (Ann. d. Physik, 49. 5. pp. 585–593, April 11, 1916.)—The non-dependence of the inversion temperature of the Joule-Thomson effect on the pressure follows only when certain approximations are introduced into the ordinary equation of state, which are here discussed. The inversion curves for air, showing the connection between the inversion temperature and the pressure, do not appear to have been measured directly, but were deduced by extrapolation by Noell (Dissertation, Munich, 1914). The author finds that Noell's curve is in good agreement, at least for regions of pressure and temperature not too near to the critical condition, with the inversion curve deduced from the author's equation of state [see preceding Abs.] and hence serves as further confirmation of the accuracy of this equation. T. H. P.

906. *Ignition of Methane-Air and Hydrogen-Air Mixtures by the Impulsive Electric Discharge.* **S. G. Sastry.** (Chem. Soc., Trans. 109. pp. 523–529, May, 1916.)—Thornton's experiments [see Abs. 82, 83 (1915), 343 (1916)] seem to indicate the existence of "stepped ignition," continuous alteration of the proportions of gas and air in an explosive mixture being accompanied by discontinuous alterations in the spark energy required for ignition. The author has made many experiments, which have been carefully checked, on mixtures of air with methane or hydrogen, and in neither instance is he able to obtain any indication of departure from a normal smooth type of curve, provided that care be taken that the experimental conditions remain unaltered throughout the measurements. Thus, the rate of break of the primary circuit of the induction coil and the condition of the secondary spark-gap must undergo no change. As regards the spark-gap, its magnitude must be constant, and it is essential that no trace of dust or dirt should become attached to the Pt-points, since otherwise the passage of the discharge would be impeded. Abnormal values of the "igniting current" occasionally observed were found to be due to the condition of the Pt electrodes and were remedied by treatment with chromic and sulphuric acids. In order to avoid possibility of error from such a cause, a standard gas mixture was tested between each pair of measurements. T. H. P.

907. *Second Virial Coefficient for Rigid Spherical Molecules carrying Quadruplets.* **W. H. Keesom** and **C. van Leeuwen.** (K. Akad. Amsterdam, Proc. 18. pp. 1568–1571, 1916. Supplement No. 139*c* to Comm. from the Phys. Lab., Leiden.)—Formulæ were previously given rendering it possible to develop in a series of ascending powers of T^{-1} the second virial coefficient for rigid spherical quadruplets—molecules the mutual attraction of which is equivalent to that of zonal quadruplets placed at their centres [Abs. 215 (1916)]. More terms of this series are now calculated, so that it may now be used down to about $\frac{1}{2}T_{inv.}(\rho = 0)$, or for hydrogen down to about 96° K., with an accuracy of 1% of B_∞; the whole region above the Boyle point is, therefore, included. T. H. P.

908. *The Energy Interchange between Matter and Ether.* **T. Wereide.** (Ann. d. Physik, 49. 3. pp. 976–1000, May 23, 1916.)—Kirchhoff's radiation laws which have been regarded as fundamental in recent investigations may be summarised in two statements, namely: (1) The radiation state of the ether in the case of stationary equilibrium, *i.e.* the dark radiation, is a universal property which depends on no special material properties. (2) The radiation of a special material substance has a definite relationship with the dark radiation.

According to the theoretical investigations of Planck, this dark radiation may be further characterised by the introduction of a new universal constant, while recent experiments have indicated that this constant plays a fundamental part in radiation other than dark. The investigation of the energy interchange between matter and ether appears, therefore, to be identical with that of discovering the nature of this constant. Since the latter is a universal characteristic it is necessary to see whether the nature of the dark radiation may be rendered explicable *via* the electromagnetic properties of the ether. Should a complete solution not be available by this method then matter itself must be called upon to assist in the explanation. Here caution must be exercised in only introducing those properties of matter

which are universal. Should this mode of attack throw light upon the nature of this constant, then the basic mechanism of radiation from matter may receive interpretation.

Section I of the paper deals with the constant as a function of the electromagnetic properties of the ether. It was found that while Maxwell's equations demanded the existence of this constant yet they afforded no explanation of its nature. Further investigation had therefore to be made, and in Section II the constant is considered as a function of a null-point energy. From this statistical investigation the author concludes that the constant is bound up with the existence of a null-point energy, since if the latter be vanishingly small then the constant becomes infinitesimal. Now as the constant is not only finite but may be determined experimentally, the relationship between the constant and a null-point energy requires more extended consideration, and Section III deals with it as a function of the exchange between ether and matter. If U_x be the energy and ν the frequency of a wave-train emitted by a linear electric oscillator then, while their values may change, the relationship $Lim\ (\nu/2U_x) = 1/h$ must always be preserved, where h is the constant referred to. It follows that in emission processes, which take place in very short intervals, $\nu/2U_x$ for the emitted ether waves will always attain the max. value $1/h$. It is known that such oscillators are physically possible, but not whether any exist which promote an energy exchange between matter and ether. The author therefore considers, as a last step, the radiation as a function of the actual oscillators, viz. the atoms. Here Rutherford's atom model receives description and application. The following result was obtained : the radiation and absorption of the atom takes place in definite intervals of time, and in order that radiation or absorption can occur certain disturbing elements must happen, *e.g.* impact of molecules or certain intensive ether vibrations, so that a characteristic number of the nucleus may be altered. Energy therefore is only emitted and absorbed in finite intervals. The general case of atomic spectra is next considered, and finally the general theory of radiation, of which atomic radiation is a special example. The particular feature of atomic radiation is not that the emitted energy has a quanta character, but that it can only have a definite value dependent on the quanta-like constitution of the atom. If the emitted energy could possess any value, then the vibration frequencies are shown to be irregularly distributed over the whole spectrum. The latter will be the case when the electrons are not united in an atom but are free to move throughout a given volume. Whenever an electron acquires an acceleration by impact at the boundary surface, energy in the form of radiation is emitted. The difference between atomic radiation and the above is that the vibration frequencies are irregularly distributed over the whole spectrum, thereby giving rise to a continuous spectrum. Between the strictly regular atomic radiation and the entirely irregular variety are transitions.

The results of the investigation are summarised by the author as follows :— The law of dark radiation may be derived from the continuous electrodynamic and statistical-mechanical equations, if a limiting property be ascribed to the ether. This property appears in the form of a null-point energy in the oscillators. In order to explain the circumstance that the dark radiation may be regarded as an electromagnetic phenomenon which depends on no special oscillator properties, the limiting relationship, given earlier, must be regarded as applicable to every energy-exchange between ether and matter. H. H. Ho.

ELECTRICITY AND MAGNETISM.

THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

909. *Electrodynamics of Conductors.* **P. Duhem.** (Comptes Rendus, 162. pp. 337–342, March 6, 1916.)—The author, in a previous paper [Abs. 802 (1916)], showed that in the case of indeterminateness of the problem of electromagnetic reflection and refraction at a plane surface separating two non-conducting homogeneous, isotropic dielectrics, the indetermination can be very simply obviated, provided the total electric and magnetic fields only are considered, by the addition of a simple condition to be satisfied by the potential of the longitudinal component of the electric field. It is here shown that an analogous condition may be found which solves the same problem, either in the case of two non-dielectric conductors, of a non-dielectric conductor, or a non-conducting dielectric. He finds, moreover, that any metallic conductor may be considered as sensibly non-dielectric. G. W. DE T.

910. *Motion of Electricity in a System of Dielectrics.* **P. Duhem.** (Comptes Rendus, 162. pp. 491–495, April 3, 1916.)—Equations previously obtained by the author [Abs. 718, 802 (1916)] are shown to lead to the conclusion that in any dielectric, or system of dielectrics, of unit magnetic permeability, the total electric field at every point and every instant is uniquely determined by the instantaneous values over the whole of the boundary; and hence that the motion of electricity within the boundary is uniquely determined by the foregoing initial conditions, together with the electrostatic potential.
G. W. DE T.

911. *Electrodynamics of a System of Stationary Conductors.* **P. Duhem.** (Comptes Rendus, 162, pp. 542–547, April 10, 1916.)—The author here shows that the results already obtained [see two preceding Abs.], supplemented by a theorem due to Roy [next Abs.], lead by mere analysis to the following general theorem:—The motion of electricity in any conductor, or system of homogeneous conductors, will be uniquely determined if there be given at every point of the boundary and at every instant, the three components of the total electric field and the normal component of the longitudinal field; or the four functions O, P, Q, R, in terms of which the total components are expressed by means of the three equations $\xi = -\partial\Phi/\partial x + \partial Q/\partial z - \partial R/\partial y$, etc., or simply by the derivates of these functions with respect to t.

It is further shown that the only true periodic oscillations in a system containing conductors leave the magnitude and direction of the total electric field unchanged at every point of any body which is not perfectly dielectric. True electric oscillations are therefore possible only in absolutely non-conducting dielectrics. G. W. DE T.

912. *Electrodynamics of Absorbing Media.* **L. Roy.** (Comptes Rendus, 162. pp. 468–470, March 27, 1916.)—The author shows that Duhem's procedure [see preceding Abs.] may be applied in the more general case of a pair of absorbing media, *i.e.* a pair of homogeneous and isotropic media, which are simultaneously dielectric, conducting, and magnetic. It is shown that

where T_1 and T_2 are the longitudinal components at the surface of separation of two such media, the following equation must be satisfied :—

$$\partial^2/\partial t^2 \cdot (T_1/\rho_1 + K_1 \partial T_1/\partial t) = \partial^2/\partial t^2 \cdot (T_2/\rho_2 + K_2 \partial T_2/\partial t).$$

If the field were entirely longitudinal, T would be continuous, so that this would become

$$\partial^2/\partial t^2 \cdot [(1/\rho_1 - 1/\rho_2)T + (K_1 - K_2) \cdot \partial T/\partial t] = 0,$$

which is not generally possible, showing that in the case of such media the electric field cannot, in general, be entirely longitudinal. G. W. DE T.

913. *On Changes in the Shape of an Electron in the Gravitational Field and the Dependence of the Mass Units on Gravitational Potential.* **J. Ishiwara.** (Tôhoku Univ., Sci. Reports, 5. No. 1. pp. 45–52, 1916.)—The author has previously developed a relativity theory of gravitation which rests upon the fundamental premise that the velocity of light *in vacuo* plays the rôle of the gravitational potential [see Abs. 752 (1916)]. The inert mass of a definite material structure at rest thereby remains constant, and is identical with the gravitational mass. The electron is here regarded as an elementary material structure. The equations of field and of motion as shown by Nordström [Abs. 1437 (1914)] can then be thrown into vector equations of a five-fold variety, which corresponds to a physical universe of a five-dimensional character. The author has further shown that a definite property must be ascribed to the electron in order that the complete 5-dimensional equation of motion may be derived from a suitably formulated principle of work. The shape of the electron when at rest should be spherical, and the mass as well as the charge should be uniformly distributed upon the surface, as the external force potential within its volume does not change perceptibly. The author finds that the radius of the electron changes inversely proportional to the external gravitational potential. The inner gravitational potential, as well as the electrostatic potential of the electron, is proportional to the external gravitational potential. This dependence of the radius on the gravitational potential is a special property of the electron. The author finally discusses the bearing of these results on the dependence of mass units on gravitational potential. H. H. Ho.

914. *Electron Theory of Metals.* **A. March.** (Ann. d. Physik, 49. 6. pp. 710–724, May 5, 1916.)—Mathematical treatment with special reference to certain metals (gold, silver, copper, platinum, lead, and aluminium), and calculations and graphs relating to them. [See Abs. 1240 (1912), 1975 (1913).] E. H. B.

915. *Specific Inductive Capacity of Certain Metals.* **F. Sanford.** (Science, 43. pp. 759–760, May 26, 1916. Paper read before the Pacific Phys. Soc.)—It is well known that in the spectra of a number of metals series of lines have been found whose wave-lengths may all be computed from a simple formula. In all these cases the wave-lengths converge towards a shortest possible wave-length for the series. In the group of the alkali metals a spectral series, whose convergence wave-length is shorter than any known wave-length in the spectrum of the respective metal, is known for each element. It is assumed that these convergence wave-lengths represent the shortest wave-lengths that can exist in their respective atoms, and that the orbital radius of the electron whose vibration frequency would give the con-

vergence number is the true radius of the central positive atom. Heydweiller's atomic radii are taken as the orbital radii of the electrons whose vibration frequencies would give the convergence numbers of the principal series in the alkali metals, and the centripetal forces required to hold these electrons in their orbits are calculated. Then, assuming the inverse square law for the attraction between an electron and its central positive charge, the force of attraction upon an electron at unit distance from the centre of its orbit is calculated for each element. If the central positive charges of the atoms were the same for different elements, then these central forces should be the same. They are, however, found not to be the same. The positive charges of these atoms have previously been computed by the author from electrolytic data. The charges here computed are not proportional to those formerly computed; hence the assumption that the atoms of the different elements have different S.I.C.'s seems to be justified. These S.I.C.'s may be computed by dividing the charges of the atoms by the respective forces which they exert upon an electron at unit distance. The S.I.C.'s are calculated in this way for the 13 elements for which the convergence numbers, atomic radii, and atomic charges have been computed. Since it is only for the alkali metals that the convergence numbers are known to belong to the principal series, it is only to these elements that we can be sure that the above arguments apply. However, the computed S.I.C.'s are proportional to the serial numbers of Rydberg for 10 of the 13 elements, and for the other three (Zn, Cd, and Tl) they increase with the serial numbers just half as fast as they do in the case of the other elements. The S.I.C.'s here computed are also shown to vary with the same atomic properties which vary with the measured S.I.C.'s of non-metallic elements. It is also shown that the S.I.C.'s of these elements are proportional to their respective atomic radii. This would make the centripetal force upon electrons revolving about and very near to these different atoms proportional to the inverse third power of their orbital radii. This is shown to be the relation that must hold in order that the kinetic energy of different electrons shall vary as their frequency, as is assumed in Planck's law, and is apparently shown in the case of electrons expelled by the action of ultra-violet light upon metals. The relative S.I.C.'s which have been calculated are as follows :—

Li ..... 35·9	Mg 134	Zn 190
Na 127	Ca 196	Cd 255
K 238	Sr 412	Tl 350
Rb 437	Ag 466	
Cs 567	Cu 346	

If the orbital radius of the outermost electron of a series be taken as the atomic radius instead of that of the innermost electron, it will not change the order of values of the S.I.C.'s calculated as above. A. W.

916. *Atmospheric Electrical Variations at Sunrise and Sunset.* **E. H. Nichols.** (Roy. Soc., Proc. 92. pp. 401–408, July 1, 1916.)—Observations of the positive and negative charge per cm.^{3}, the air-earth current, and the conductivity were made with two Ebert electrometers and a Wilson compensating gold-leaf electroscope. Potential gradients were measured from the charts of the Kelvin water-dropper. The two Ebert instruments were used to record the simultaneous values of the positive and negative charges per cm.^{3}. Three consecutive 5-minute readings were taken immediately before sunrise or sunset and three immediately after. Taking the means of

the 15 minutes before and of the 15 minutes after sunset, it is apparent that a decrease of about 20 % occurs in all the quantities (positive charge, negative charge, air-earth current, and conductivity) at the time of sunset. The individual 5-minute readings show that this is not brought about by a sudden change at the instant of sunset, but by a gradual decrease throughout the whole 30 minutes in all the elements. The effect seems to be as strong in the winter months as in the summer. The *sunrise* readings show that the effect is not so pronounced at sunrise as at sunset. A similar investigation was carried out on the potential gradient, making use of two years' records from the water-dropper. There is generally an increase in potential gradient both at sunrise and sunset. This is well-marked in the winter but negligible in the summer. Again there is no sudden change at the instant of sunrise or sunset, but a gradual one throughout the 30 minutes.

The effect was tried of applying a correction for the diurnal variation of potential gradient at the appropriate time of day, and it was found that after doing this the sunrise and sunset effects were still apparent. J. S. Di.

917. *Ball Lightning on Puy de Dôme.* **E. Mathias.** (Comptes Rendus, 162. p. 642, April 25, 1916.)—On April 15, 1916, the phenomenon of ball lightning was observed on three occasions—at 18h. 20m., 18h. 30m., and 18h. 50m., taking the form of a brilliant fireball with somewhat hazy contour, afterwards changing to an oval with long axis horizontal. The discharges appeared sensibly stationary, and lasted for some 2 or 3 secs. Their colour was white tinted slightly mauve. C. P. B.

DISCHARGE AND OSCILLATIONS.

918. *Theory of Ionisation by Collision.* **K. T. Compton.** (Phys. Rev. 7. pp. 489–496, April, and pp. 501–507, and 508–517, May, 1916.)—In the first paper of this series exact expressions are obtained for the velocity distribution among the negative ions of inelastic gases and approximate expressions for this distribution in elastic gases and mixtures.

In the second paper an expression is derived for α, the number of new ions formed by inelastic impacts of a negative ion in 1 cm. of path, and this expression is found to receive good experimental support.

In the third paper the functional relation between α, X and p (where X is the potential gradient and p is the pressure) is derived. Also an equation for α is obtained which conforms to the best experimental data. The departure of some experimental data from this theory is shown to arise from the use of impure gases.

In all the discussion it is assumed that velocities due to thermal agitation are negligible and that no complex ions or clusters are formed in the experiments. E. H. B.

919. *The Existence of an Atomic Structure in Electricity. The Phenomena of Photoelectric Effects.* **D. Konstantinowsky.** (Ann. d. Physik, 49. 8. pp. 881–906, May 23, 1916.)—This is a reply to a criticism by E. Meyer and W. Gerlach of the author's previous work on the subject [see Abs. 1122, 1306 (1915) and 11 (1916)]. An introduction gives an historical survey of the question, and the rest of the paper is subdivided as follows:—Criticism of the atomicity of photoelectric effects; Criterion on the existence of an atomic structure; Application of the criteria in the measurements of E. Meyer and W. Gerlach; Comparison of the deviations with the expected

experimental errors; Determination of absolute values from the resistance laws; The method of Meyer and Gerlach for the determination of absolute values; Meyer and Gerlach's proof of the correctness of their method of calculation; The Brownian movements; and a complete summary of the conclusions arrived at. A. E. G.

920. *Variation of the Positive Emission Currents from Hot Platinum with the Applied P.D.* **O. W. Richardson** and **C. Sheard.** (Phil. Mag. 31. pp. 497–505, June, 1916.)—The incentive to the present investigation was an observation recorded by one of the authors to the effect that when a fresh metal wire is positively charged and heated in a vacuum the relation between current and e.m.f., when due allowance is made for the decay of the current with time, is approximately linear, although it is known that no measurable quantity of negative ions is emitted by the wire at the temperature of the experiment. Since it would be expected that saturation should occur with a quite small potential under these circumstances, this phenomenon seemed to call for further examination. The experiments have been made with two forms of testing vessel: (1) a glass tube in which the electrodes are a loop of heated Pt-wire and a Pt-plate, (2) a brass cylinder with an axial Pt-wire. The wires are heated electrically, the temperature being controlled and measured by placing the wires in one arm of a Wheatstone bridge, which was actuated by the main heating-current in the usual way. Successive curves showing the relation between the current and applied voltage at different times are given. The first current-e.m.f. curve was not completed until about $2\frac{1}{2}$ hours had elapsed from the commencement of the heating, as some time was occupied in preliminary adjustments. The curve is slightly convex to the voltage axis, but is almost linear, in agreement with the one referred to. The approximately linear relation did not hold down to $V = 0$, but the curves became concave to the voltage axis at low voltages. As the heating of the wire was continued the first effect was to rotate the curve about the origin towards the potential axis. This corresponds to a decay of the currents in approximately equal proportions at all potentials. With further heating the curves developed a flat region in the middle. With subsequent heating the increased current above 280 volts continues to decrease faster than the currents of lower voltages, until after 30 hours it is scarcely noticeable. After heating the wire, which was positively charged, to a relatively high temperature (718° C.), and subsequently observing at the original temperature (452°), the resulting current-e.m.f. curves are very peculiar: they are characterised by a very sharp maximum at about 240 volts, which is more marked with descending than with rising potentials. It seems that these peculiarities might be due to the glass insulation becoming charged to a high potential under the influence of the copious emission of positive ions which had occurred at the higher temperature. The brass tube apparatus was therefore constructed in order to eliminate this possibility. The current-e.m.f. curves for low potentials are peculiar, although similar observations have been recorded before. The current is greater in the neighbourhood of 2–4 volts than it is at somewhat higher potentials, indicating that one of the effects of increasing the applied potential is to diminish the number of systems giving rise to the emission. After continued heating the results show a tendency to become more irregular, but the main features are obtained too frequently to be likely to be due to observational errors. These features are: (1) A steady rise to a flat region between 80 and 160 volts, (2) a further rise from 160 to 280 volts, followed by (3) a comparatively flat region between 320 and

400 volts. This type of curve seems to point to the existence either of two different types of ions or of two different processes involved in the emission. These particular indications of duplicity were not noticeable in the first apparatus.

The experiments show that the freshening action produced by admitting air diminishes with successive repetitions of the process, but a stage has not been reached at which the air ceases to produce an effect. The effect occurred both when the inner surface of the brass tube was left untouched and when it was thoroughly scraped with emery-paper. The increased sensitiveness could not be removed by mere pumping. Similar effects were observed when the wire was raised for a time to a higher temperature than that at which the observations of the positive current were made. The changes were more pronounced when the hot wire was negatively charged and discharging electrons to the cold electrode during the temporary heating. It appears that, with successive treatments, the tube gets into such a state that the passage of a negative discharge from the wire at a higher temperature produces an increase in the positive emission, subsequently measured at the original lower temperature, which does not increase with the applied potential at high potentials. The progressive increase of the currents, with increasing p.d., which has been recorded in the various cases tested, might be due to a variety of causes. It is shown, however, that it must be due either to an effect of the electric field on the emission at the hot wire, or to an effect which it may produce indirectly by the impact of the ions on the negative electrode. Some experiments lead to the conclusion that the second of these alternatives is the correct one.

In these experiments it appeared that the large currents at high potentials could be cut down by the application of rather small transverse magnetic fields, indicating that the carriers of part of the discharge were negative electrons liberated at the cold electrode. However, further experiments showed that this influence of a magnetic field was not always to be relied on, so that the results of this test cannot be regarded as decisive. A. E. G.

921. *Variation of Thermionic Currents with Potentials.* **H. Lester.** (Phil. Mag. 31. pp. 549–559, June, 1916.)—Experiments seem to show conclusively that at the cold electrode, ionisation of a volatile film could not account for the observed lack of saturation, and that there could be no considerable amount of vapour around the hot surface. Since these hypotheses concerning the location of the phenomena causing lack of saturation are apparently untenable, there remains only the hypothesis that the effect is due to actions at the hot surface. To get at the nature of these phenomena a detailed study of the peculiarities connected with initial emissions was undertaken. In all, 23 different wires were studied under various conditions of purity, surface-cleanness, pressure, etc. It was known that water-vapour actively modifies thermionic currents, so water-vapour was in all cases excluded from the apparatus. In part of the experiments the wires were sprayed with salts, and in some cases they were heavily coated with CaO or BaO. It is shown that there is an initial growth in the value of lack of saturation, and that there is a peculiar over-shooting effect. These facts, together with more generally known behaviour of initial thermionic currents, indicate that the observed peculiarities of initial thermionic emission may be explained as due to the influence of ionised surface-films. In an appended note some curious glow effects obtained with CaO and BaO kathodes are described. A. E. G.

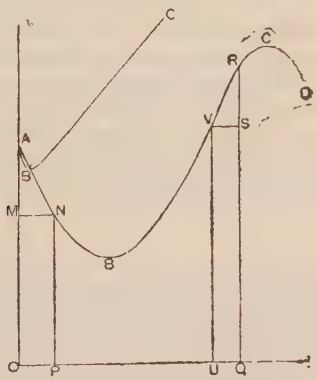
922. *Potential Measurements in the Nickel Arc.* **W. Frey.** (Ann. d. Physik, 49. 8. pp. 937–965, May 23, 1916.)—Describes research on the potential gradients in the nickel arc, and on the way these are affected by variations of gas pressure, length of arc, current, and temperature. The same typical forms of arc were observed with nickel as have previously been observed with copper and iron by Hagenbach and Veillon, and photographs were taken of the arc in air and in nitrogen. With the arc burning in an atmosphere of coal-gas at about 20 mm. pressure, distinct striations were obtained. Measurements of the potential and current for the arc in nitrogen show that the Ayrton equation is not satisfied. The watt-current curves are always straight lines, which meet in a point to the left of the watt axis. The curves relating watts with arc-length are all convex towards the watt axis. The influence of the gas pressure on the potential-fall across the arc is only very slight, and no effect of the gas pressure on the anode- and kathode-falls could be detected by the test electrodes used. It was found, however, by means of the test electrodes, that the anode- and kathode-falls decrease slightly with increased current strength, also that the kathode-fall is somewhat greater than that at the anode. The kathode-fall is independent of the arc length ; and so the anode-fall increases with the arc length. The potential gradient in the gas column of the arc is practically constant for different arc lengths, though it is slightly greater for very long arcs. This latter result is perhaps to be explained by the temperature effect of the electrodes in short arcs on the gradient in the gas column. [See Abs. 1672 (1900).] A. W.

923. *Electrical Discharge between Concentric Cylindrical Electrodes.* **C. T. Knipp.** (Science, 43. pp. 787–789, June 2, 1916.)—These experiments with concentric cylindrical electrodes were performed in class demonstration. The discharge consists of an ordinary 3-quart battery jar. A hole bored through the bottom receives the evacuating tube, the junction being made airtight with ordinary sealing-wax. The lip of the jar is ground flat to receive the plate-glass lid. The electrodes are concentric cylinders and may be made of sheet Al—one electrode to fit the inner wall of the jar, and the other mounted on a cylinder of glass tubing about 1½ in. diam., which in turn is supported accurately concentric. Outside connections to the electrodes are made by fine bare copper wire run out through the wax joints. The potential employed to produce the discharge was furnished by a high-potential storage battery of 1000 volts. Two methods of operating are described. This form of discharge vessel offers a method for the study of the striations and their relative spacing with reference to the impressed discharge potentials. These effects are best shown when the vacuum is not too high and the discharge potential is adjusted to give on the kathode (inner cylinder) a patch about 1 cm.² in area. A. E. G.

924. *Length of Kathodic Dark Space.* **G. Zanobini.** (N. Cimento, 11. pp. 193–206, March–April, 1916.)—The author has made experiments in order to ascertain the manner in which the length, d, of the kathodic dark space depends on the current density σ and has also compared the values of d with those of the pressure p when the electrodes used fill completely the discharge tube. Cylindrical tubes were employed with equal Al electrodes, the distance between the latter being kept constant even in tubes of different diams., and their distance from the extremities of the tube as small as possible. The usual precautions were taken. The minimal values of the intensity, i, were such that the surface of the kathode was completely covered by the negative

light, but excessive intensities were avoided in order to prevent such complications as emission of gas from the electrodes, heating of the gas, etc. The variation in d is found to become less marked as the current-density increases. Thus, in narrow tubes with relatively high initial current-density, variations of i are small, and in tubes of very small diam. they are scarcely perceptible. It has been found that, with increase of i, the positive column modifies in the sense corresponding with a diminution of pressure. The results now obtained show, on the other hand, that the increase of i is accompanied in the kathodic region by consequences analogous to those due to increase of pressure. If such hypothetical increase of pressure be due to numerical increase of the positive ions condensed before the kathode, the use of a perforated kathode with a large part of the discharge tube beyond it should obviate or restrict the increase of pressure and also the consequent variation in length of the dark kathode space; experiment shows that this is actually the case. As regards the dependence of d on the pressure, the relation $d = a + b/p$, deduced by Thomson from Ebert's results, is found to hold fairly well, the values of the constants changing abruptly at a certain critical pressure, which depends not merely on the nature of the gas, but also on the dimensions of the discharge tube and of the kathode. T. H. P.

925. *Influence of Magnetic Field upon a Charged Conductor in Rarefied Air.* **A. Righi.** (Comptes Rendus, 162. pp. 670–673, May 1, 1916.)—The results here described show under a new form some results obtained during some previous experiments [Abs. 123, 646 (1911)]. The hypothesis of magneto-ionisation was introduced as the result of those experiments. A tube containing air at 0·1 mm. pressure has two coaxial cylindrical electrodes, A and B, 5 cm. long, A being 5 mm. and B 20 mm. diam. A is connected with a gold-leaf electroscope, B is earthed. The following are typical experiments:—(*a*) A is



positively charged to a potential slightly less than that of discharge. The gold leaves remain apart for a long time but so soon as the pole of an electromagnet is brought near they collapse. The discharge is, however, a partial one. (*b*) Leaving the electromagnet in position, A is given a negative charge. (The electromagnet used must give a powerful field for this experiment.) At first a potential larger than that of discharge is reached without the gold leaves collapsing. If, now, the magnetising current is broken or decreased, a partial discharge occurs and the leaves fall together. A characteristic curve for the effect of the magnetic field on the potential of discharge has been

established. The intensities of the field are plotted as abscissæ, and the discharge potentials as ordinates. This curve has in general the form ABCD, the depression ABC being chiefly due to the action of the magnetic field favouring ionisation by collision. Experiment A has to do with the descending part AB. Let the applied potential OM be less than OA. If a magnetic field is applied and its value increased until it reaches OP, discharge occurs, for the existing potential OM is now equal to the discharge potential PN corresponding to the intensity of the field. For experiment (*b*) the part BC of the curve applies. First of all a field OQ, to which a potential QR corresponds, is applied. When the potential QS is less than QR naturally no discharge occurs, but if the field be removed or its value diminished to OU the leaves collapse. A. E. G.

926. *Absorption of Gases in Vacuum Tubes and Allied Phenomena.* **S. Brodetsky** and **B. Hodgson.** (Phil. Mag. 31. pp. 478–490, May, 1916.)—Experiments made under various conditions indicate that the absorption of gases in vacuum tubes is probably a phenomenon of some complexity and that, with metallic electrodes, the effect is due principally to absorption of gas by the disintegrated metal, although it may depend partly on the liberation of the alkali metals by electrolysis of the glass and chemical combination of these metals with the gas. Many of the apparently contradictory results obtained by different experimenters are reconcilable by means of such dual explanation. Experiments in tubes of materials other than glass would be of interest. T. H. P.

927. *Electric Oscillations on purely Dielectric Bodies.* **E. Duhem.** (Comptes Rendus, 162. pp. 736–740, May 15, 1916.)—Mathematical treatment which obtains equations to be satisfied in the dielectric and others which hold for the surface of separation of two dielectrics. E. H. B.

928. *Electric Waves on Dielectric Wires.* **H. Zahn.** (Ann. d. Physik, 49. 8. pp. 907–933, May 23, 1916.)—This paper describes an experimental arrangement by which the author has succeeded in producing and measuring electric waves along dielectric wires as shown to be theoretically possible by D. Hondros and P. Debye and first realised experimentally by Rüter and Schriever. The experiments are in good agreement with the theory especially when it is considered that the latter relates to ideal conditions. [See Abs. 142 (1910) and 367 (1916).] E. H. B.

929. *Variation of Resistance with Voltage at a Rectifying Contact of two Solid Conductors, with Application to the Electric Wave Detector.* **D. Owen.** (Phys. Soc., Proc. 28. pp. 173–200 ; Disc., 200–203, June, 1916.)—An account of an investigation, the primary object of which was to determine the nature of the physical actions occuring at a rectifying contact. Resistance characteristics are given for various contacts, some including a mineral, some in which both elements are metals. It is shown that a *specific characteristic* may be drawn for any given pair of materials. The experimental results are in accordance with the view that the actions are thermoelectric, the main determining factors being the thermoelectric power and the temperature-coefficient of electric resistance.

Based on the law of constancy of the voltage-coefficient calculations are given showing the best value of the resistance of the telephone in a wireless receiving circuit in which the contact detector is employed. The influence of a polarising voltage is also traced.

The use of the combination of rectifier with a d.c. galvanometer as indicator of the balance point in an a.c. bridge is examined, and it is shown that the minimum detectable alternating voltage cannot be reduced much below a millivolt. AUTHOR.

ELECTRICAL PROPERTIES AND INSTRUMENTS.

930. *Vibration Galvanometer.* **W. Jaeger.** (Archiv f. Elektrot. 4. Nos. 7 and 8. pp. 262–268, 1916.)—The author discusses the theory of moving-needle and moving-coil vibration galvanometers and compares their action with that of d.c. instruments. He then deduces from his equations the best methods of using the galvanometer. [See Abs. 961 (1906).] I. W.

931. *Design of Galvanometers.* **F. Wenner.** (Bureau of Standards, Bull. 13. pp. 211–244, 1916. [Sci. Papers No. 273.])—This paper discusses the relations between (1) the operation constants, namely, the external critical resistance, the deflection and ballistic periods, and the sensitivity in the particular conditions for use in which the galvanometer is intended, and (2) the intrinsic constants, namely, the inertia, damping, restoring, and displacing constants and the resistance, for critically damped galvanometers. The best relations for these quantities for attaining the desired sensitivity whether to voltage or current or to voltage or current impulses, are indicated, and an outline of the design of galvanometers to give specific performances for each of these purposes is given. The detail design is only briefly considered, being outside the scope of the paper. For the formulæ and their application the original paper should be consulted. W. H. G.

932. *Damping Factor of d'Arsonval Galvanometer.* **P. E. Klopsteg.** (Phys. Rev. 7. pp. 543–544, May, 1916.)—In a recent paper [Abs. 466 (1916)] L. Pyle states that appreciable errors arise in obtaining the damping factor of a ballistic galvanometer by raising θ_1/θ_2, the ratio of successive throws, to the power $\frac{1}{2}$, and shows that this power should more exactly be $2t_1/T$, where t_1 is the time taken to obtain the first throw and T is the damped period. It is now pointed out that the direct determination of the quantity $2t_1/T$ is difficult, and that it is preferable to raise θ_1/θ_2 to the power $(1/\pi)(\tan^{-1}\pi/\Lambda)$, where Λ is the logarithmic decrement. This quantity is already given in published tables. If Λ is less than 0·184, the damping factor may be replaced by $(\theta_1/\theta_2)^{\frac{1}{2}}$ with an error of only 0·3 %. A. J. M.

933. *Inductance Coefficients of Two Iron-cored Solenoids with Axes Inclined.* **H. Lorenz.** (Archiv. f. Elektrot. 4. Nos. 7 and 8. pp. 256–261, 1916.)—The author considers the case of two solenoids with iron cores, placed with their axes inclined to one another in such a way that one solenoid is able to rotate about an axis which passes through a point on the axis of the other and is also perpendicular to the plane containing the axes of the solenoids. He obtains expression for the self- and mutual inductance and for the turning moment on the rotating solenoid. Dispersion and the external field are neglected. The movable solenoid occupies a position corresponding to the armature of a dynamo, while the fixed solenoid corresponds to the field magnet. The iron core of the former may be a circular plate or ring. I. W.

934. *Distribution of Current between a Gas Column and a Metallic Shunt.* **R. F. Earhart.** (Phys. Rev. 7. pp. 447–450, April, 1916. Lum. Électr. 34. pp. 139–140, Aug. 5, 1916.)—These experiments were made for the purpose of

studying some of the conditions under which a current of electricity passing through a gas might be diverted through a metallic circuit, and to study the quantitative distribution between a gas column and a metallic circuit under several conditions. The general form of apparatus used consists of a cylindrical glass tube closed at each end by a flat electrode. The tube is provided with a pump connection. Within the tube perforated metallic partitions are placed parallel to the end electrodes: these partitions are provided with terminals sealed through the walls of the tube; they can be connected through a switch and low-resistance galvanometer. A current from a high-potential storage battery sent through the tube is measured either with a milliammeter or shunted galvanometer. A considerable number of experiments are made with tubes of different size, under varying pressure conditions and for currents varying from a few microamps. to 50 milliamps. The effectiveness of electrodes in taking current out of a conducting gas column depends more upon the state of division of the electrodes than upon their superficial area. The effect of offering an alternative path through an external metallic conductor is to decrease the total current. For small currents an increase through the shunt circuit occurs when the total current increases. Such increases are proportional to the total current, but the value of the factor depends on the pressure of the gas and form of the electrodes. This proportionality factor holds up to a limiting value which depends on the pressure employed. Further increase in total current results in a decrease in current through the shunt circuit.

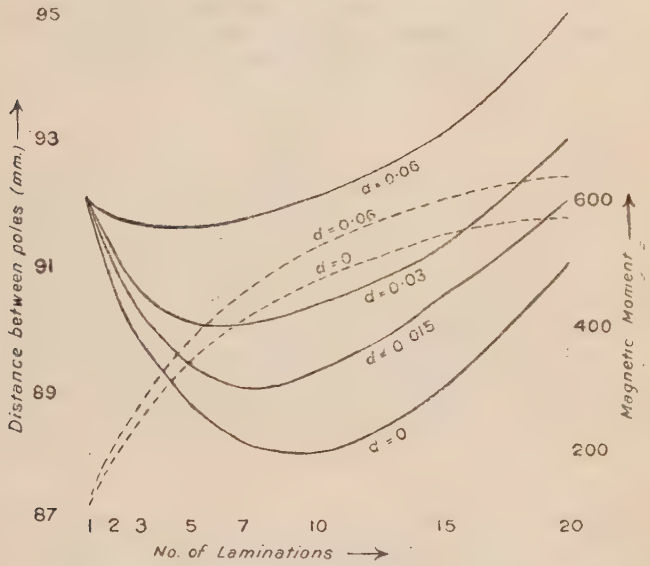
A. E. G.

935. *Electric Furnace for the Continuous Action of the Gaede Diffusion Pump.* **E. Rüchardt.** (Phys. Zeits. 17. pp. 141–142, April 15, 1916.)—Heating by means of a Bunsen burner is unsuitable for the continuous action of the diffusion pump, variations of the gas pressure and the disturbing influence of every draught necessitating frequent regulation and constant supervision. Experiments made with the object of overcoming these difficulties have resulted in the construction of an electric furnace of special type which the author now describes. Using a constant current of 2·9 amps., the oven was run for 3 hours without regulation, the temperature of the mercury vapour remaining at 117° to within 1 deg. T. H. P.

ALTERNATING CURRENTS AND MAGNETISM.

936. *Influence of Alternating Currents of Decreasing Intensity on the Magnetisation of Iron.* **G. J. Elias.** (K. Akad. Amsterdam, Proc 18. No. 8. pp. 1299–1309, 1916.)—A mathematical paper. Assuming that iron consists of a very great number of elementary crystals, and that "perfect" hysteresis exists, the resulting magnetisation of the iron is expressed by means of a series the separate terms of which represent the successive magnetisations caused by reversing and diminishing the applied field. Different forms are then obtained for the series for the cases in which (*a*) the e.m.f. of the magnetising current is constant and the resistance is gradually increased, (*b*) the e.m.f. is diminished by equal steps, and (*c*) the magnetising current decreases in the form of a damped oscillation, *e.g.*, condenser discharge current. Finally, the effect is considered when a diminishing alternating field is superposed on a constant field. It is concluded that the resulting magnetisation is then principally determined by the initial max. value of the alternating field, unless the constant field lies below a certain limit. The first portion of this conclusion has been verified by experiment. G. E. A.

937. *Note on Laminated Magnets.* **W. Brown.** (Roy. Dublin Soc., Proc. 15. pp. 137–140, June, 1916.)—Scoresby in his "Magnetical Observations" (1839) shows that the strength of a laminated magnet is increased when the plates are separated. Jamin [Comptes Rendus, 1872–5] has also studied the effect of lamination. The present author measures the magnetic moment and distance between the poles of such magnets. The magnets used were built up of glass-hardened strips of clock-spring steel, 10 cm. long, 0·5 cm. wide, and 0·06 cm. thick. They were magnetised in a field of about 1200 c.g.s. units. The laminations were clamped in a brass holder and experiments made with the pieces (1) in contact, (2) separated by strips of paper of thicknesses



$d = 0{\cdot}015$ cm., 0·03 cm., and 0·06 cm. respectively. The moments were determined by the end-on magnetometer method and the polar distance by moving a small compass needle, turning in a vertical plane, from one end of the magnet to the other, when the latter was placed in an E.-W. direction. The results are represented in the Fig., where the full-line curves show the variation of polar distance with number of laminations and the broken-line curves the variation of magnetic moment. The author concludes that the best magnet to use with the given steel would be one made up of 9 laminations in contact ($d = 0$) when the cross-section is practically square and the poles at the minimum distance apart. L. L.

938. *Moment of Momentum existing in a Magnet.* **W. J. de Haas.** (K. Akad. Amsterdam, Proc. 18. No. 8. pp. 1281–1299, 1916.)—An electromagnet is hung from a unifilar suspension with its magnetic axis vertical and performs torsional oscillations. The current is reversed automatically, so that it can be observed whether the magnet has a moment of momentum depending upon and reversed with its magnetism. In one case the moment of momentum was detected and found to be $1{\cdot}35 \times 10^{-4}$. But by theory (A. Einstein and W. J. de Haas, Ibid. p. 696, 1915) this must be $1{\cdot}13 \times 10^{-7}$ times the magnetic moment, which gave 1200 for the magnet instead of 1400. E. H. B.

939. *Magnetic Susceptibility of Gases.* II. **W. P. Roop.** (Phys. Rev. 7. pp. 529–542, May, 1916.)—The author has applied the method of the gas manometer to the determination of the magnetic susceptibility of oxygen, this method avoiding various systematic errors inherent in other methods and reducing observational errors owing to its high sensitivity. The details of the apparatus used are described. Carbon dioxide is employed as comparison substance, its susceptibility being taken as zero; a slight uncertainty is thus introduced, but this does not exceed 2 % of the value for oxygen. The following points bearing on the measurements are discussed: purity of the gases, precautions in filling and operating manometer, diffusion in the manometer, temperature control, determination of sectional area of manometer, correction for curvature of manometer bore and measurements of field intensity. With field intensities of 3400–7500, the value of $K \times 10^7$ for oxygen is found to be 1·46; with field intensities of 100–135, and 21,000, Curie and Piccard [Abs. 1736 (1913)] respectively found the values 1·52 and 1·41. T. H. P.

940. *Magnetic Susceptibility of Manganese Nitride.* **T. Ishiwara.** (Tôhoku Univ. Sci. Reports, 5. No. 1. pp. 53–61, 1916.)—In the temperature interval from 600° to 1600°, manganese and nitrogen give rise to three ferromagnetic substances, namely two nitrides and probably a solid solution. One of the nitrides is Mn_5N_2, but in the other two cases the compositions could not be ascertained, although the characteristic thermomagnetic curves and their critical points serve for differentiation. Ammonia affects manganese at high temperature in the same way as does nitrogen, excepting that a paramagnetic nitride, Mn_3N_2, is formed; the existence of Wedekind and Veit's ferromagnetic substance, Mn_7N_2, could not be confirmed. The varying values obtained by different investigators for the susceptibility of Mn are explainable as resulting from the effects of nitrogen; for pure Mn the value $\chi = 9{\cdot}66 \times 10^{-6}$ is given. T. H. P.

941. *Results of some Magnetic Observations during the Solar Eclipse of August* 21, 1914. **L. A. Bauer** and **H. W. Fisk.** (Terrest. Magn. 21. pp. 57–86, June, 1916.)

RADIOGRAPHY AND ELECTROPHYSIOLOGY.

942. *Experiments on X-ray Transformers.* **C. Déguisne.** (Phys. Zeits. 17. pp. 106–112, April 1, 1916.)—The article is concerned with the characteristics of the high-tension transformers that are used in conjunction with a synchronously rotating contact for the generation of X-rays. The function of the contact is to connect the vacuum tube across the h.t. winding at definite instantaneous values of the voltage. A series of oscillograms are reproduced showing the variation of the primary and secondary currents of the transformer and the internal voltage, the latter being obtained by means of an extra winding connected only to the oscillograph. In order to place the curves for the above-mentioned quantities in juxtaposition with the no-load values for the purpose of comparison the contact is arranged to make contact every other period.

The X-ray transformer differs in its action from the induction coil on account of the fact that in the former the primary circuit is permanently closed, whereas in the latter the primary circuit is open when the secondary current starts. The energy available in each discharge with

the induction coil is therefore strictly limited to the energy magnetically stored at the beginning of the discharge, whereas with the transformer the energy-flow is not limited in this manner and will depend greatly on the type of load, different results being obtained with hard and with soft tubes. The oscillograms show that the secondary current has a large reactive effect on the primary current and that the internal e.m.f. is distinctly flattened at the moment of the passage of the secondary discharge. The secondary voltage shows pronounced indentations and very different shapes with different tubes and different place-adjustments of the rotating contact. The indentations correspond with indentations in the curve for the secondary current, but the relation between them is complicated by the fact that the secondary current has different values at different parts of the winding. A comparison of the relative phase-displacements of the current at an end and in the middle of the secondary winding shows that the surge due to a discharge is propagated from the ends into the middle of the winding with a velocity of $1{\cdot}2 \times 10^{10}$ cm./sec. The same value is obtained from the total length of the winding and the time interval between successive indentations. The distribution of the flux along the length of the core of the transformer is affected by the surge, search coils at different points showing that the induced e.m.f. near the centre contains a marked harmonic whose period is the time taken for the surge to traverse the length of the secondary winding, and that this harmonic is less marked near the ends of the coil as in this position the surges from the two ends tend to cancel their effects. The high-frequency surge in the induced e.m.f. is shown separately by the device of connecting two search coils in opposition. This is performed with search coils near the centre and at different positions along the core. With soft tubes the surges are much smaller in amplitude than with hard tubes. A. J. M.

943. *A New Incidence Indicator.* **Charlier.** (Archives d'El. Médicale, 24. pp. 131–132, May, 1916.)—The indicator consists of a small vertical metallic tube 60 cm. in length and square in section. On this glides a collar which can be fixed so as to act as a kind of support for the Röntgen tube. A second collar in which a shorter tube glides at right angles to the vertical tube is soldered to its lower extremity. A third branch, also in the horizontal plane, is fixed at right angles to the shorter tube, and the combination is arranged in such a position that the normal ray from the tube strikes the third branch near its end. At the point of contact of the normal ray a lead marker is fixed. The trace of the normal ray is thus always given by the image of this marker, and is automatically obtained on the photographic plate. The vertical branch being graduated in cm. the distance of the photographic plate from the antikathode, and of the latter from the subject, can be instantly found. A diagram of the apparatus is given. A. E. G.

944. *The Lilienfeld Tube for Röntgen Rays.* **F. J. Koch.** (Dresdner Elektrot. Verein, 10. No. 10. p. 85. Elekt. Zeits. 37. pp. 185–186, April 6, 1916.)—Lilienfeld found that up to a certain degree the occurrence of a discharge is independent of the goodness of the vacuum when a glowing kathode is employed in the tube. The special form of Röntgen tube designed by Lilienfeld, in which an ordinary metal-filament lamp is used as a glow-electrode, is here described with details as to working. There is also a brief account of a valve tube for obtaining unidirectional current, constructed on the Lilienfeld principle with a glow kathode. A. E. G.

CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

945. *Active Modification of Nitrogen.* VII. **R. J. Strutt.** (Roy. Soc., Proc. 92. pp. 438–450, July 1, 1916.)—The paper deals with the circumstances of the activation of nitrogen by the electric discharge [see Abs. 769 (1915)]. Current and potential measurements of jar discharges being difficult to interpret, an Evershed-Vignoles dynamo giving up to 15 milliamps. at 5000 volts was used, though the effects are then weaker. In the first series of experiments a long discharge tube, 18 mm. diam., was so arranged that the two disc electrodes of Al were 130 mm. apart, but could together be moved up and down the tube; thus the flow of nitrogen across the tube would traverse different portions of the discharge column, the intensity of the glow being estimated in an observation tube. It was then found that the yield of active nitrogen was greatest close to the kathode; the yield diminished in the negative glow, to zero in the Faraday dark space, and increased again to a steady value (about half the former intensity) in the positive column. The Crookes space was too narrow to admit of taking measurements in it. In other experiments it was ascertained that the glow was twice as intense in a narrow tube, 6 mm. in diam., than in a wide tube 15 mm. in diam., whilst the potential gradients were practically the same; other experimenters had found higher potential gradients in narrower tubes, but they had not used such large currents (13 milliamps. at 6 mm. pressure), and their nitrogen had probably been more contaminated by electrode gases. As regards the length of discharge traversed, a positive column of 12 cm. length gave more effect than a column 6 cm. long, but the 12 cm. seemed to be about the maximum; the discharge thus both produces and destroys active nitrogen. This was confirmed by other experiments with T-shaped tubes. When the apparatus was so arranged that a jar discharge passed in A, and a dynamo-current discharge in B, at right angles to A, the intensity being observed in C (A, B, C being tubes in series), the B discharge destroyed the glow produced by the A discharge. The commercial nitrogen of these experiments had been purified with phosphorus and phosphorus pentoxide, but still contained some foreign gas acting as catalyst. When purified with sodium and then mixed with 1/820 part by volume of oxygen, both the glow and kathode-fall increased, the latter from 270 up to 345 volts, but the fall of potential in the positive column was not affected; these kathode-fall measurements do not agree with the values of Warburg, who has studied these features more fully. The addition of ethylene (instead of oxygen) to the nitrogen also brightened up the afterglow, but made the kathode-fall readings irregular. So far the nitrogen had always been at a pressure of about 5 mm. (or less) of mercury. With nitrogen at atmospheric pressure, the glow is much less conspicuous, but can be shown by fixing iron wire electrodes in a silicon tube, through which the gas is flowing, and providing the tube with a 1·5-mm. hole opposite the discharge gap; a jar discharge is required. A luminous jet of nitrogen is then seen to issue from the hole; it has a length of about 15 mm., whilst at low pressures luminous columns several metres in length can be produced, lasting in extreme cases half an hour; ordinary nitrogen itself seems to have a destructive effect on active nitrogen. When the experimental conditions favour kathode disintegration (uncondensed discharge from a copper wire

protruding from a silica sheath), and when some disintegrated metal is carried away by the stream of nitrogen, a tongue of green light is seen showing the copper lines; more volatile metals show their spectra when heated in active nitrogen. H. B.

946. *The Atom and the Molecule.* **G. N. Lewis.** (Ann. Chem. Soc., J. 38. pp. 762–785, April, 1916.)—It is urged that the conventional distinction between inorganic and organic chemistry should be replaced by a classification which is roughly identical between "polar" and "non-polar" substances; thus potassium chloride is an extreme "polar" type, whilst methane is an extreme "non-polar" type. The polar type in general is mobile and reactive, has high dielectric constant, associates forms molecular complexes, and has a condensed-structure. The non-polar type is inert, non-ionising and non-ionised, does not associate, and has a "frame" structure. The extent to which polarity is developed depends largely on the strength of the polar environment, *e.g.* salts are highly ionised when merely fused, but hydrogen chloride requires the polar environment provided by dissolution in water.

To account for Abegg's law of valence and countervalence, a cubical atom is adopted for all elements; illustrations are given showing the union of these atoms by single and double bonds, and the question of triple bonds is discussed.

In general, colour and a high degree of polarity go hand in hand, as in the great class of organic dyes. Both phenomena are due to the same cause, namely, the weakness of the constraints acting on one or more electrons. T. M. L.

947. *The Combining Volumes of Hydrogen and Oxygen.* **F. P. Burt** and **E. C. Edgar.** (Roy. Soc., Phil. Trans. 216. pp. 293–427, June 5, 1916.)—As a result of the authors' measurements of the ratio of the combining volumes the value 1·00772 is obtained for the atomic weight of hydrogen, which is very nearly the arithmetic mean of the results of Morley and of Noyes. The true value is concluded to be very close to 1·0077. L. H. W.

948. *A Recalculation of Some Work on Diffusion.* **A. Griffiths.** (Phys. Soc., Proc. 28. pp. 255–257, June, 1916.)—Gives corrections to certain papers published by the author and B. W. Clack. [See Abs. 928 (1909), 785 (1915), 395 (1916).]

949. *Relative Densities of Alkali-metal Amalgams and Mercury.* **J. R. Withrow.** (J. Phys. Chem. 20. pp. 528–531, June, 1916.)—Attention is called to the erroneous impressions concerning the relative densities of alkali-metal amalgams and mercury, which are encouraged by descriptions of the preparation of such amalgams in the literature and standard text-books. In the case of potassium amalgam, especially, the solid amalgam is represented in some cases as lying below the mercury, as if it were specifically heavier. The author points out, however, that solid alkali amalgam, both potassium and sodium, when placed in mercury, float; and the fact that the amalgam, in some cases, appears to be heavier than mercury, is due to its adhering to the vessel. The recalculated data of Maey are in agreement with this. A. F.

950. *Extraction of Radium from Carnotite Ores.* **H. Schlundt.** (J. Phys. Chem. 20. pp. 485–494, June, 1916. Chem. News, 114. pp. 50–53, Aug. 4,

1916.)—At the present time the carnotite ores of S.W. Colorado and E. Utah constitute the principal source of radium in the U.S.A. The carnotites consist of a sandstone with a clay binder variably impregnated with the mineral carnotite, a hydrous potassium uranium vanadate containing Ba and Ca. By boiling carnotite ores with concentrated H_2SO_4 the Ba and Ra compounds present are converted into bisulphates which remain in solution in an excess of the acid, and may then be separated from the insoluble components by filtration followed by washing the residue with concentrated H_2SO_4. From the acid liquors thus obtained the Ra is recovered by diluting with water, whereby barium-radium sulphate is precipitated. The experiments outlined in this paper are based on the preceding principle. A. B. W.

951. *Tungsten-Molybdenum System.* **F. A. Fahrenwald.** (Am. Inst. Mining Eng., Bull. No. 114. pp. 1049–1055, June, 1916.)—Alloys of this system were prepared by compressing mixtures of W and Mo powder into briquettes and heating with an electric current in an atmosphere of hydrogen. The solidus curve for the series was obtained by means of optical pyrometric temperature measurements and checked by comparing the fusing current with a standardised wattage-temperature curve. The equilibrium diagram shows no critical points, and as a result of the thermal and microscopical analysis the metals are reported as being completely isomorphous. All the alloys of the series are malleable and ductile under proper conditions, and curves for hardness, both in the compressed and heat-treated state and after forging to a reduction of 60 %, are smoothly convex, the latter showing max. hardness at about 50 % of each metal. The curve showing equiaxing temperatures is also smoothly convex having a maximum of 2050° at about 60 % W.

The melting-point of tungsten is taken as 2500° C., and of Mo as 3200° C.

C. O. B.

952. *Invar and Related Nickel Steels.* (Bureau of Standards, Circ. No. 58. [68 pp.], Washington, 1916.)—This circular forms a very complete account of the history and properties of nickel steels. It includes sections on the magnetic, electrical and mechanical properties (strength, hardness, elasticity, polish), the resistance to corrosion, density, sources of supply, and commercial and scientific applications. The thermal expansion is considered at length, and in this connection invar is made the subject of a special section which treats of (*a*) its transitory length-variations following temperature changes, (*b*) permanent changes of length at constant temperature, (*c*) effects of heat treatment on forged bars, (*d*) behaviour of drawn bars as compared with forged ones, (*e*) elongation of invar with time, (*f*) range of the transitory length-variations following temperature changes, (*g*) rapidity of invar transformations, (*h*) effect of composition on instability, (*i*) reproducibility of the properties of invar, (*j*) a note on the investigation of nickel steels now proceeding at the Bureau of Standards. It is hoped shortly to publish an account of these.

J. W. T. W.

953. *Standard Test Specimens of Zinc-Bronze.* I. *Preparations of Specifications.* **C. P. Karr.** II. *Microstructure.* **H. S. Rawdon.** (Bureau of Standards, Techn. Papers, No. 59. [67 pp.], Washington, 1916. Mech. Eng 38. pp. 10–12, July 7, 1916.)—Zinc-bronze is an alloy of 88 % Cu, 10 % Sn, and 2 % Zn, and is commonly known as Admiralty metal, Government bronze, or 88–10–2 alloy. It has been studied by a large number of investigators, and

the author gives a brief summary of their work. Experiments have been carried out with a view to determining the best methods of casting, the best shape of test-piece, and the best casting temperature for the alloy. The results show that the best type of test-bar is the cast-to-size form, poured into a dry sand mould. Such a sand casting gives mechanical properties which are superior to those obtained from a chill casting, but the results can be made of almost equal value by annealing the chill castings at temperatures ranging from 500° to 700° C. It was anticipated that some definite casting temperature would be found at which the best and most uniform mechanical properties would be obtained, but the series of tests showed that there was a considerable range of temperature, viz. 1120° to 1270° C. over which good and regular results were obtained. Annealing improved the ductility without seriously influencing the strength. The elastic limit of the bronze was found to vary between 15,000 and 17,000 lbs. per sq. in. Cooling curves showed the melting-point of the alloy to be about 980° C. There was a marked thermal change at 780° and a more feeble one at 530°. On the results of this work a specification has been drawn up, and the author compares the suggested specification with the Navy specification and also with the standard specification of the American Society for Testing Materials. Investigation of the microstructure of the alloys showed that the addition of the small percentage of Zn did not affect the theoretical structure of the metal. On the basis of Guillet's coefficient of equivalence of Sn with regard to Zn being 2, the alloy has been regarded as the structural equivalent of a pure bronze containing 11·1 % of Sn. The method and temperature of casting only affected the structure indirectly by determining the rate of cooling and the amount and distribution of the enclosures. A table has been drawn up showing that the mechanical properties and the characteristic appearance of the fracture can be correlated with the microstructure. Of the various structural features affecting the mechanical properties, oxide films were found to exert by far the greatest influence. The effects of heat treatment have also been studied, and it appears that a very valuable study of the effect of annealing in removing the deleterious effects of the presence of enclosures might be made.

F. C. A. H. L.

954. *Electrical Conduction in Anisotropic Liquids.* **T. Svedberg.** (Ann. d. Physik, 49. 4. pp. 437–455, March 24, 1916.)—Measurements of electrical conductivity were made, over a range of temperatures, using *p*-azoxyphenetol and *p*-azoxyanisol as solvents, and hydrogen chloride, picric acid, and 2 : 3-oxynapthoric acid as solutes. The temperature coefficient of electrical conductivity was about twice as great in the anisotropic as in the isotropic state. On passing downwards through the clearing-temperature an abrupt decrease of 14 % was observed in the case of hydrogen chloride, and 20–23 % in the case of the two organic electrolytes; this might be attributed to diminished ionisation or to diminished ionic mobility, but it is a remarkable fact that the fluidity actually increases by 60 % at this point whilst the dielectric constant is unchanged. T. M. L.

955. *Molecular Attractions in Solutions.* **Berkeley.** (Nature, 97. p. 301, June 8, 1916.)—It is suggested that by measuring the compressibilities of two pure liquids, and of their mixtures over a considerable range of concentrations, it may be possible to disentangle the various internal attractions as they are influenced by the mixing, *e.g.* the attraction of A for A, and of B for B, as well as the new attraction of A for B. Experiments to test this view have been begun, but are not yet complete. T. M. L.

956. *Study of apparent Specific Volume in Solution.* **Le R. D. Weld.** (Phys. Rev. 7. pp. 421–430, April, 1916.)—The variations with the temperature of the densities of various solutions of potassium chlorate, and also the variations of the density with the concentration, the temperature being constant, have been studied. The solutions were nearly saturated, and in some cases supersaturated. From the results the "apparent specific volume" of the solute has been calculated, this being defined as "the volume of the solution containing 1 gm. of the solute, minus the natural volume of the pure water entering into it, at the same temperature." A discussion of the results is given, but it is necessarily inadequate until the behaviour of solutions of other solutes have been investigated. T. S. P.

957. *Study of the Hydrogen Electrode, the Calomel Electrode, and of Contact Potential.* V. **W. F. Clarke, C. N. Myers,** and **S. F. Acree.** (J. Phys. Chem. 20. pp. 243–265, March, 1916.)—A detailed investigation to improve the working of the hydrogen and calomel electrodes by improved temperature regulation, diminished evaporation, more handy form of apparatus, and better methods of storage, whereby a reproducibility of 0·01 millivolt may be more easily obtained.

The hydrogen electrode under these improved conditions is an easily reproducible and constant system, extremely sensitive to small amounts of impurity, and for this very reason specially suited for the rapid and accurate determination of small hydrogen-ion concentrations, as in cases of catalysis by acids. T. M. L.

958. *Application of the Theory of Allotropy to Electromotive Equilibria.* IV. **A. Smits** and **A. H. W. Aten.** (K. Akad. Amsterdam, Proc. 18. pp. 1485–1498, 1916.)—It has been shown that the phenomenon of passivity is explainable in a simple manner by the application of the theory of allotropy to the electromotive equilibrium, metal-electrolyte [see Abs. 372 (1915)]. According to this theory the metal is complex, and it may be that the complexity is based on the fact that in the metal there is an ionisation equilibrium which may be expressed by the equation, $M \rightleftarrows M^{\cdot} + \theta$. Further, with metals which form ions of different valencies, several such ionising equilibria may exist side by side, thus: $M \rightleftarrows M^{\cdot\cdot} + 2\theta$ and $M \rightleftarrows M^{\cdot\cdot\cdot} + 3\theta$. The assumption of such an ionisation equilibrium in a metal leads to the important conception of the solubility product of the metal. This conception is utilised to explain the following electromotive processes: (1) Dissolution of metals by halogens; it is shown that base metals should possess relatively high, and noble metals relatively low, solubility products. (2) Dissolution of metals in pure water; metals acting most strongly on water are those with comparatively high solubility products. (3) Dissolution of metals in acids. (4) Dissolution of metals in a solution containing a ferro- and a ferri-salt. (5) Dissolution of a metal by withdrawal of metal ions. Various new relations for the p.d. between metal and electrolyte are considered, and it is shown that, where the solubility of the metal ions is not very great and that of the electrons very small, the metal ions will not go into solution so much as when the electrons do not check the action, and that, on the other hand, the electrons will go more into solution than when they are attracted by the metal ions. Thus, the liquid co-existing with a base metal is unsaturated so far as metal ions are concerned, but supersaturated with respect to the metal so far as electrons are concerned; this is, therefore, the reason why the metal is negative with respect to the liquid. For a noble metal exactly the reverse holds.

It is shown that the p.d. between a metal and, say, pure water can be sharply defined and possesses a finite value which is determined completely by the solubility of the electrons and by that of the metal ions; if the solubility of the metal ions is greater than that of the electrons, the metal will be charged negatively with respect to the water and positively in the opposite case.

Other points considered are the introduction of the solubility product of the metal into the p.d. equation, and passivity and polarisation. The conclusion is drawn that a metal with the most simple constitution can exhibit the phenomenon of anodic polarisation or passivity as well as, and in virtue of, the same circumstances as a more complicated metal. These phenomena will, indeed, present themselves with any metal when the removal of metal ions and electrons from the metal takes place more rapidly than their formation in the metal. T. H. P

959. *Copper Voltameter.* **A. K. Datta** and **N. Dhar.** (Am. Chem. Soc., J. 38. pp. 1156–1160, June, 1916.)—It was found to be immaterial whether the experiments were conducted in an atmosphere of CO_2 or hydrogen; the essential thing is to prevent the access of oxygen into the voltameter. Sulphuric acid is essential for ensuring a good result. It prevents the hydrolysis of the copper sulphate solution, which causes a deposition of cuprous and cupric oxide on the kathode; it also diminishes the concentration of the copper ions in the solution, due to the increase of SO_4'' ions and also due to the formation of complex copper salts as indicated by the equation $H_2SO_4 + CuSO_4 \longrightarrow H_2Cu(SO_4)_2$.

Cane-sugar and glucose can be substituted for alcohol with equal efficacy, and tartaric acid is a decidedly better substitute, and with it better results can be obtained even with currents of feeble strength. It has been observed that copper sulphate solution appreciably dissolves copper, and this dissolution depends greatly on the concentration of copper ions in the solution, and also on the temperature. The action is more pronounced in presence of sulphuric acid when added to prevent hydrolysis. In measuring high currents this does not materially affect the results of the experiments, as the copper deposition is rather rapid, while in the case of measuring feeble currents the copper is deposited very slowly, and the copper sulphate solution finds sufficient time to dissolve it appreciably. The improvement made by the addition of tartaric acid is probably due to its forming a very good complex with copper ions, and thus diminishing the concentration of the copper ions. F. E. S.

960. *Silver Voltameter.* **J. Obata.** (Math. Phys. Soc., Tōkyō, Proc. 8. pp. 437–452, May, 1916.)—The electrolyte was in general prepared by the method suggested by the Bureau of Standards [see Abs. 744 (1914)]. The anode was a circular plate of Ag with electrically deposited Ag on its surface, and the Smith form of voltameter was used in the experiments. The voltage of the Weston normal cell at 20° C. was determined as $1{\cdot}01826_9$ int. volts, a value very closely agreeing with that found by the Washington Electrotechnical Committee in 1910. In all 21 separate experiments were made between Oct. 25, 1915, and Feb. 4, 1916. The mean of any ten successive measurements differs from the mean by not more than 15 parts in a million. The effect of acid present in the electrolyte was quantitatively determined. The following relation was obtained by the method of least squares: $y = -4{\cdot}2x + 0{\cdot}02x^2$, where y represents the decrease of the silver deposit and x the mean kathode

acidity, both being expressed in parts of a million. A simple voltameter in which the kathode is a thin cylindrical Ag plate and the anode a silver ring is suggested for general use. The following table gives the results obtained with this modified form and the Smith form of voltameter :—

Date.	Approximate Time.	Approximate Current.	Deposit in Smith Form Voltameter.	Deposit on the Silver Ring.	Difference, Ring – Standard.
Jan. 18, 1916	7028 sec.	0·509 amp.	3·99968 gm.	3·99954 gm.	$-3{\cdot}5\times10^{-5}$
Feb. 8, „	7029	„	4·00018	4·00013	—1 „
Feb. 15, „	7028	„	4·00020	3·99995	—8 „

F. E. S.

961. *Kathode Scattering in Electrolysis.* **A. H. W. Aten.** (K. Akad. Amsterdam, Proc. 18. No. 8. pp. 1374–1384, 1916.)—The amount of disintegration of a lead kathode, using different electrolytes, has been investigated. The kathode was so arranged that it could be weighed before and after the electrolysis in order to ascertain the extent of the disintegration. The anode was of carbon, and during the electrolysis the solution was stirred vigorously. The disintegrating power of the metal is taken to be the ratio of the number of gm.-equivalents disintegrated to the number of faradays used ; this ratio is called A. Using normal solutions of Na_2CO_3, Na_2SO_4, and NaOH, and lead kathodes, it was found that A approaches a limiting value of about 1·7 with increase in the current density up to 2·56 amps./cm.^{2}. A increases from 1·28 to 1·52 as the concentration of a solution of Na_2CO_3 decreases from 2-normal to 0·125 normal, the current density (D) being 0·32 amp./cm.^{2} at 15°. With n-Na_2CO_3 and $D = 0{\cdot}13$, A decreases from 1·25 to 0·90 as the temperature rises from 15·5 to 49°. Solutions of K_2CO_3, KOH, and K_2SO_4 behave similarly to those of the sodium salts, whereas in solutions of calcium salts the disintegration is very small, $A = 0{\cdot}05$ for $D = 2{\cdot}56$ with n-$CaCl_2$. With mixtures of KCl and $CaCl_2$ the disintegration decreases as the percentage of $CaCl_2$ increases. Also the addition of a lead salt to the solution of a potassium salt diminishes the disintegration of the kathode.

In dilute sulphuric acid a lead kathode is disintegrated to much the same extent as in solutions of sodium and potassium salts, but the influence of the concentration of the solution and of the duration of the electrolysis is much greater ; also, the disintegration takes place only for comparatively large current densities.

The results obtained are explained by the author in the light of the views already put forward by Haber [Abs. 1752 (1899)], Haber and Sack [Abs. 176 (1903)], and Sack [Abs. 747 (1903)], the disintegration in solutions of sodium and potassium salts being due to the primary formation of a Pb-Na or Pb-K alloy. In the case of the disintegration of a lead kathode in sulphuric acid electrolytes, it is assumed that hydrogen is deposited in the atomic condition at the kathode. This atomic hydrogen is soluble in the lead, and penetrates into the metal to a certain depth before it forms molecular hydrogen. Molecular hydrogen is less soluble than atomic hydrogen, so that as soon as it is formed it disrupts the lead and causes disintegration. T. S. P.